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THE

NATIONAL GEOGRAPHIC MAGAZINE.

Vol. I. 1889. No. 4.

IRRIGATION IN CALIFORNIA.

By Wm. Hammond Hall.

Mr. President and Gentlemen of the Society:

When I was invited to address this society I had no material at hand on the subject. I have come to the east without any notes or memoranda whatever, from which to prepare a lecture or address, no statistical data which would make a paper valuable, no notes of characteristic facts to render an address interesting, and no time to write anything to guide me in any way to a proper treatment of the subject. Some of your members have thought that I have written something worthy of being read, and hence this invitation to address you. But, even if they are right, people who can write cannot always talk, so if I fail in this address, I shall hope, on the basis of their opinion, that you will find in the reports I have written something worthy of reading. The subject has been announced as the "Problems of Irrigation in the United States." I should like very much to speak broadly on that subject, but I am unable to do so, for the reasons I have given, and shall have to speak rather of irrigation in California, trusting that something which is said, may, perchance, be valuable in relation to the subject at large. Irrigation in the far west, generally, is attracting a vast deal of attention. This is particularly the case on the Pacific Coast—the field with which

I am specially acquainted. I apprehend that although many gentlemen present have a comprehending and definite appreciation of the subject at large, many others do not appreciate the value and importance of irrigation. In the arid parts of California (for we do not admit that California is as a whole arid) it is a vital matter. There it is a question of life, for the people. Not more than one-sixth of the tillable area in the State can sustain a really dense population, without irrigation; two thirds of it will not sustain even a moderate population, without irrigation; while one third will not sustain even a sparse population, without such artificial watering. Think well over these facts. They are very significant. I doubt whether they are generally appreciated in California itself.

I have no doubt many persons are familiar with the geography of the State, but, doubtless, some are not. California has a coast line of 800 miles and a width of from 140 to 240 miles. It is traversed almost throughout its length by a great mountain chain extending along near the eastern boundary, which is called the Sierra Nevada, and by a lesser range, more broken and less unified, running parallel to the coast, called the Coast Range, the southern extension of which, after joining the Sierra Nevada, is called the Sierra Madre, and at the further extremity, the San Jacinto and San Diego mountains. Within the interior of the State, looked down upon by the Sierra Nevada on the east, and closed in by the Coast Range on the west, is the great interior basin—the valley of the San Joaquin and Sacramento rivers—forming a plain 450 miles long, with an average width of from 40 to 60 miles. Outside of the Sierra Madre in the southern part of the State, and within the Coast Range, is another interior valley, nearly 100 miles in length and from 20 to 30 miles in width, and outside of the Coast Range, and lying near to the ocean, is a plain whose length is from 60 to 70 miles, and width 15 to 20 miles. These three areas—the great interior valley, the southern interior valley, and the coast plain of the south—are the principal irrigation regions of the State. Numbers of smaller areas, as those in San Diego county, come in as irrigation regions of less importance, and the scattering valleys along the Coast Range further north, as the Salinas, etc., will come forward in the future as important irrigable districts of the State. Still further north, in the interior, there are the great plains of Lassen and Modoc counties, and some scattering valleys in Shasta county, where

irrigation is also practiced or is being introduced, and these are on a par with the districts of San Diego county, in the matter of rank as irrigation regions. East of the Sierra Nevada, and at their base, lies the Owen's river country, an area suitable for irrigation, where irrigation is necessary and where it is being introduced. Upon the great Mojave desert and the Colorado desert, there is at present no irrigation. The water supply is very scanty. This is an irrigation region of the future, but it is not regarded by Californians as a practicable one at present.

With this general idea of the State, we will now look at the rainfall and water supply. The State contains 157,440 square miles of territory, of which 17,747 drain into the ocean north of the Golden Gate, 21,606 drain into the ocean south of the Golden Gate, 35,942 drain into the interior basins, and 82,080 drain out at the Golden Gate. Of this territory which drains out by the Golden Gate, 38,187 square miles comprise the Sacramento valley, 31,805 square miles the San Joaquin valley, and 4,004 the country draining directly to the bays, making the 82,080 given above as the whole area.

The necessity for irrigation in California, and the relative necessity in different parts of the State, are shown by the distribution of rainfall. The San Joaquin valley has an average of less than 10 inches of rainfall, the Sacramento has an average of between 10 and 20 inches. The great deserts of the Mojave and Colorado have an average of less than 10 inches, and in certain localities only 3 to 4 inches. The Salinas valley, a small portion of the coast above Los Angeles, and a portion of the interior valley of the south, have also an average of less than 10 inches.

So, we may say, that the great irrigation regions of California have average amounts of rainfall varying from almost 0 up to 20, but generally less than 10 inches. This rain is distributed in four or five months of each year, with some slight showers in one or two months other than these; the remainder of the year being absolutely dry, with no rainfall whatever. Hence, you will see at once, the necessity for the artificial application of water in California. In the older countries of Europe, where irrigation has been practiced for centuries, for instance, in Spain, where water is used more extensively than in California, the annual mean rainfall ranges between 10 and 25 inches. In the irrigation regions of France, the mean rainfall ranges from 10 to 40 inches; in the irrigation regions of Italy, the rainfall is between

20 and 35 inches—for instance, in the valley of the Po, the classic land of irrigation, the annual precipitation is from 23 to 45 inches. There are none of those European irrigation regions where the rainfall is less than 10, and generally it is over 20 inches. But you will see that the most of the Californian irrigation regions have less than 15 inches, some less than 10, and the greatest rainfall of any large irrigable region in California is 18 inches, or, exceptionally, for smaller regions, 25 inches; while in Europe, the maxima are from 25 to 40 inches in countries where irrigation has long been practiced. It follows, then, that there is no place in Europe where it is so much needed as over a large part of California. Another reason why the necessity is felt in our Pacific Coast State, is found in the character of our soils; and not alone the surface soils, but the base of the soil—the deep subsoils. We have soils exceptionally deep; soils which extend below the surface to 50 feet, underlaid by loose sand and open gravels, so that the rainfall of winter is lost in them. The annual rain seldom runs from the surface. It follows that these lands are generally barren of vegetation without the artificial application of water.

Considering now the sources of water-supply: we have in the southern part of the State many streams which flow only for a few weeks after rainfall, and other streams which run two or three months after the rainy season. But there is not a stream in all California south of the Sierra Madre (except the Colorado, which has it sources of supply outside of the State) which flows during the summer with a greater volume than about 70 to 80 cubic feet per second—a stream 15 feet in width, 2 feet deep, and flowing at the rate of 2½ to 3 feet per second—a little stream that, in the eastern part of the continent, would be thought insignificant. The largest stream for six months in the year, in all southern California, is the Los Angeles river. The Santa Ana river, the next largest, flows from two sevenths to one third as much; the San Gabriel, the next largest, has perhaps two thirds or three fourths as much as the Santa Ana; and so, a stream which will deliver as much water as will flow in a box 4 feet wide and 14 feet deep, at a moderate speed, during summer months, would be regarded as a good-sized irrigation feeder in that southern country. In the greater interior basin or central valley, we find other conditions. Here we have a different class of streams. The great Sierra Nevada receives snow upon its summits, which does not

melt till May or June and July. The melting of these snows is the source of supply of the streams; so that, while in far southern California, with two or three exceptions, the greater flow of water in the streams is almost gone by June, in this central region it is the period of the height of irrigation, and the streams are flowing at their maximum. Kern river presents about 2000 to 3000 cubic feet of water per second; King's river presents in the maximum flow of the season about twice to three times as much as Kern river; the Tuolumne river about as much as King's. As we go farther north, the Sacramento river presents more than three times as much as the Tuolumne, so that in the northern part of the great valley, where the rainfall on the valley itself is greatest, and, consequently, the necessity for irrigation is least, the irrigation supply increases; and conversely, the greatest area of irrigation in the valley and the greatest necessity for it, is, in general, where the water supply is least.

About ten years ago irrigation was commenced in California. The Roman Catholic priests, coming from Mexico where irrigation had long been practiced, introduced it. They established missions among the Indians, started cultivation, and by the labor of these Indians built the original irrigation works. The practice of irrigation was extended in San Diego county, as far as we are able to trace, to several thousand acres; in San Bernardino county in the southern interior valley, they thus cultivated and watered, perhaps 2000 acres; and in Los Angeles county there were possibly 3000 acres irrigated under Mexican rule. Traces of the old mission works are found in San Diego, San Bernardino and Los Angeles counties, and as far north as Monterey county.

Then came the gold fever, when canals were dug throughout the foot-hills of the western slope of the Sierra Nevada, for the supply of water for the mining of gold; and these canals have since, in many instances, been turned into feeders for irrigation. Several thousand miles of irrigation ditches have thus been created from old mining ditches. In 1850, a band of Mormons came from Salt Lake into the San Bernardino valley - they bought a Mexican grant rancho there, took possession of some old mission works, constructed others and started irrigating. That was probably the first irrigation colony, on a large scale, composed of others than Mexicans, in California. In 1856, some Missouri settlers went into the valley of Kern river, diverted water from that stream, and commenced irrigation upon a small scale. In 1858, the waters

of Cache creek, in the Sacramento valley, were taken out for irrigation. In 1858, the waters of King's river were taken out and utilized for irrigation. These instances represent in general outline the commencement of irrigation in the State. Now we have in the neighborhood of 750,000 or 800,000 acres actually irrigated each year, and that represents what would ordinarily be called an irrigation area of 1,200,000 acres; and these are commanded by the works—reasonably within the reach of existing canals—an area of about 2,500,000 acres.

In the organization of irrigation enterprises there is great diversity. Commencing with the simplest form, we have a ditch constructed by the individual irrigator for his own use; we have then successively ditches constructed by associated irrigators without a definite organization, for the service of their own land only; ditches constructed by regularly organized associations of farmers, with elected officers; works constructed by farmers who have incorporated under the general laws of the State and issued stock certificates of ownership in the properties, for the service of the stockholders only; works where incorporations have been formed for the purpose of attaching water stock to lands that are to be sold, bringing in the element of speculation; then works where the organization has been effected with a view of selling water-rights; and finally, organizations that are incorporated for the purpose of selling water. There is a great difference between the principles of these methods of organization, and the practical outcome is a great difference in the service of water and in the duty of water furnished by them. In selling water, measurement of volume is made by modules—the actual amount of water delivered is measured—or it is sold by the acre served, or in proportional parts of the total available flow of the season.

The general character of the irrigation works of the State varies very much with the varying conditions under which it is practiced. In the San Joaquin valley, King's river, for instance, comes out of the mountains nearly on a level with the surface of the plain, cutting down not more than a few feet below its banks; and hence but little labor is required to divert its waters out upon the lands to be irrigated; but farther north, the Tuolumne, as another example, comes out of the mountains in a deep cañon, and the foot-hills extend far down the plain on each side. It is easily seen, then, that it will require a million or more dollars to divert from the latter stream the amount of water diverted from

King's river by the expenditure of a few months' work, by a small force of the farmers themselves. On King's river, individual and simple cooperative effort is sufficient to bring water enough upon the plains to irrigate thousands of acres, while in the case of the Tuolumne river it is absolutely necessary to have associated capital in large amount—an entirely different principle of organization from that which was originally applied on King's river and the Kern and other rivers in the southern part of the great central valley. In discussions on the subject of irrigation some people have advanced the idea that the works should be undertaken by the farmers, and that capital should have nothing to do with them. That may do very well where the physical conditions will admit of such a course, and where nothing but the farmers' own service depends upon it; but the great majority of the streams of California are of such a character that the work of the farmers can avail nothing. There must be strong associations and large capital. For this purpose special laws are required. On the Santa Ana, in San Bernardino county, water has been easily diverted, and such is the case with every stream in the interior valley of San Bernardino and Los Angeles counties.

Capital for the first works was not required. The water was procured by primitive methods and the works were simple. But in San Diego, an entirely different condition of affairs prevailed. There the waters are back in the mountains, twenty or twenty-five miles from the coast, and the irrigable lands are close along the coast, or within ten or twelve miles of it. To bring the water out of these mountains requires the construction of ditches following the mountain sides for 20 to 35 miles. But simple ditches do not answer, because of the great quantity of water lost from them. So the companies have resorted to flumes, and even to lining the ditches with cement. Thus in San Diego, individual effort is out of the question. Farther north again, in the great interior valley, King's river is a stream where cooperative and individual effort have been efficient, although it requires a greater amount of capital there than in the southern interior valley. In the southern interior valley, perhaps, $10,000 would often build a ditch and divert all the water that the supply would furnish. On King's river the works have cost from $15,000 to $60,000 each; on Kern river the works have cost from $15,000 to $250,000 each; and on the Tuolumne they will cost from $1,000,000 to $1,200,000 apiece. On Merced river, the cost has

been $500,000 for one work. Taking the streams from San Joaquin river north, that come out of the Sierra Nevada, up to the northern end of the valley where the Sacramento river enters it, every important stream comes into the valley within a deep gorge. The beds of several of the northern streams are so filled up with mining debris that diversion from them would be comparatively easy, but in their natural state there is not an important stream north of the San Joaquin which could be utilized for irrigation by any other means than through the agency of capital in large amount. On the west side of this great valley the tillable strip is comparatively narrow. It is on the lee side of the coast range of mountains. Precipitation is made first on the seaward face of the Coast Range, and then crosses the valley, dropping upon the inland face of the outer range very little more than upon the valley itself, where the precipitation is only about 10 inches. So that we have no streams coming out of the Coast Range into the southern part of the interior valley specially noteworthy as irrigation feeders. But as we go northward the Coast Range becomes wider, and the big mountain basin containing Clear Lake furnishes a large supply of water to Cache Creek, probably enough for 10,000 acres. Stony Creek flows between two ridges of the Coast Range, and out on to the plains, furnishing about the same amount of water; but still there are no streams from the Coast Range into the valley that are comparable with those of the Sierra Nevada. In the northeastern corner of the State, on the great plains of Modoc, we have the Pit river, a stream of very considerable volume, but its waters are in comparatively deep channels, not very well adapted to diversion, and the consequence is, they have been utilized to a very small extent, only on small bottom-land farms. The whole stream can be utilized, however, and the country is thirsting for water.

The practice of irrigation in California is as diverse as it could well be. California, as you know, covers a very large range in latitude, but a greater range in the matter of climate and adaptibility to the cultivation of crops. In the southern portion of the State, the orange and the banana and many other semi-tropical fruits flourish. In some localities along the foot-hills of the Sierra Nevada, also, those fruits flourish, particularly the orange and the lemon. In the valley of San Joaquin, wheat is grown by irrigation, and in some places profitably, and in Kern county quite profitably (were it not for high transportation charges), because

the cost of distributing and applying water has been reduced to a minimum. These tracts have been laid out with as much care and precision as the architect would lay out the stones in a building and the masons would place them. Irrigation is conducted in some large river deltas with the greatest ease, scarcely requiring the use of the shovel. The lands are so laid off with the check levees that by simply opening gates in the proper order, as the irrigator superintendent sees about how, the water flows on it and covers it a successive plane or "checks" in their order, without requiring any stand by water, and finally flowing off without material waste. This is the perfection of irrigation by the broad or submerging system,—a method wherein the slight of the ground is first ascertained, plotted by contours, and then ditches to hold the water, constructed with scrapers, are then run out on right grade contours—not perfectly level, but on very gentle slopes.

There is no portion of [illegible] part of the State where the check method is applied as it is in Kern county. The practice in San Bernardino is to irrigate orchards by running water in ditches between the rows of trees. Orange trees planted 24 to 30 feet apart are irrigated by [illegible] furrows, 6 to 8 between rows. Lemon [illegible] orchard, which slope varies from about 1 foot to a hundred to 4 or 5 in a hundred. In Los Angeles county they make basins about eight feet in diameter around each tree, forming basins 4 or 5 to the 12 feet, and another system is to have one of the trees. Into these basins the water is conducted by a ditch, and the basins being filled, the water is allowed to remain and soak away. The low, nearly flat valley lands, when irrigated, are generally divided into square "checks," without respect to the slope of the ground, and the surface is simply flooded, the water standing 6 inches to a foot in depth.

In the northern part of San Diego, [illegible] county, clover is grown on high ridges where there is 10 to 15 feet in a hundred, and irrigated in [illegible] furrows [illegible] apart horizontally—and the water is allowed to soak into the ground from open ditch furrows.

These are the five principal methods of applying water: by the check system; by ridges, by the basin method, by the border method as applied to low valleys; and by contour ditches on hillsides. The method selected for any particular locality is determined not alone by the crop to be cultivated, but also

by the slope of the land and the character of the soil. In Arizona, as in all places where such crops are cultivated, in the southern part of the State, where they are most generally used, water cannot be applied by the flooding system, for the reason that it would be lost more by evaporation of the soil, so that the trees would not be helped. It is necessary on such land to cultivate immediately after a rain or irrigation, and the method of applying it is governed more by the slope than by the character of the soil.

The first irrigation very marked and important effects for a large irrigation. For instance, in passing the great plateau in the San Juan valley, where crops are cultivated there [illegible] it was [illegible] feet down to soil water, a sandy dry soil for nearly [illegible] feet, and it was the rule there that the great plateau, at any time in the past, [illegible] that soil was or was beyond the reach of the root in [illegible] plateau, water came in the surface ditches, moistened the ground, caused several inches of [illegible] and the crops [illegible] and [illegible]. Water does not [illegible] the soil to [illegible] for the crop at the surface water [illegible] and [illegible] crops [illegible] unnecessary. The amount of water taken from [illegible] by the first irrigation [illegible] the [illegible] to the depth of [illegible] feet [illegible] field and plant it. It simply sinks into the ground, or flowed out [illegible] for the great plain. Taking those areas of [illegible] north and south and east and west, I found that where the depth to soil water had before irrigation been [illegible] feet, it was [illegible] feet or [illegible] and the surface [illegible]. The soil water stood [illegible] the plain in the form of [illegible] plain, the slope rising [illegible] 50 feet [illegible] a few miles on the west and north. On the south and southwest the surface of the water-bearing [illegible] much more steep. In the Kern River country, we have a somewhat similar phenomenon. Irrigation in the upper part of the Kern delta affects the water in the wells 6 or 8 miles away. As I remember the effect as felt at the rate of

about a mile a day, that is to say, when water is used in irrigating the upper portion of the delta, or of Kern island, as it is called, the weeds commence to rot a mile away in twenty-four hours, and five miles away in perhaps five days.

In the southern portion of the State, in San Bernardino county at Riverside, we find no such effect at all. There it was found to be 90 feet to soil water before irrigation and it was a general rule, 50 to 90 feet to it. Water applied on the surface in some places has never even wetted the soil all the way down and wells dug there, after irrigation had been practiced for years, have passed dry ground for 25 or 30 feet before getting down to where soil waters have wetted it from below. The consequences of these phenomena are useful. In the first place in the country that first opened with water, the duty of water—the quantity of land which a given amount of water will irrigate—was increased. Starting with a duty of not more than 50 acres to a cubic foot of water per second, we now find that in some localities, this amount irrigates from 100 to 150 acres, and that some lands no longer require irrigation. In the southern portion of the State however, the cubic foot of water irrigates no more than at first, and it is scarcely possible that it will ever irrigate much more than 50 acres, as irrigation goes on in the far southern portions of the State, will be effected chiefly through the better construction of canals and irrigation works of delivery and distribution. In Tulare valley, the duty of water will increase as the ground dries up.

In Fresno, a county which was regarded as phenomenally unhealthy, malarial fevers now are found, while in San Bernardino, at Riverside, such a thing is rarely known. Coming to Bakersfield, a region which before irrigation commenced was famous for its malarial fevers, known as unhealthful throughout all the State—where soil water was originally within 15 feet of the surface, irrigation has almost entirely rid it of the malarial effects. Chills and fever are rare now, where before irrigation they were prevalent. What is the reason that where chills and fever prevailed, irrigation has made a beautiful country, while where chills and fevers were not known, irrigation has made it unhealthful? I account for it in this way: in the Kern river country before irrigation was extensively introduced, there were many old abandoned river channels and sloughs, overgrown with swamp vegetation and overhung by dense masses of vine growing trees

Adjacent wide were in a number of cases swampy reclamation ground waters at and within 10 or 20 feet of the surface, and there was in many parts an impermeable stratum between such surface and these waters. In other words, general swamps conditions prevailed, and malarial epidemics followed by chills and fevers were the result. Irrigation brought about the clearing out of many of these old swamps ways, and these are as irrigating canals. The lands were cleared off and well watered, fresh water was introduced through these channels from the main rivers flowing at the bottom, and the swamps he condition of the country was changed to one of a well-tilled agricultural neighborhood with streams of fresh water flowing through it; and the result, as I have said, was one happy in its effect of making the climate as obvious and healthful.

Considering now the case of the King's river or the Fresno country, the lands there were a rich alluvial deposit, about large in vegetable matter which for many ages perhaps has been, except as watered by the rains of winter, dry and desiccated. Such water was deep below the surface. Then irrigation came. Owing to the nature of the soil, the whole country filled up with the water. Its absorptive qualities being great and its natural drainage defective, the vegetable matter in the soil, subjected to more or less moist and excessive moisture, has decayed. The fluctuation of the surface of the ground waters at different seasons of the year—such surface being at times very near the ground surface, and at other times 6 or 8 feet lower—has in itself tended to the unhappy influences which the presence of the waters engendered. The result has been, when taken with the general overgrowth of the country with vegetation due to irrigation, a vitiation of the atmosphere by malarious outpourings from the soil. The advantage of the pure atmosphere of a wide and dry plain has been lost by the miasmatic poisonings arising from all over wet and ill-drained neighborhood, with the results, as affecting human healthfulness, of which I have already spoken. The remedy is of course to drain the country. The example is but a repetition of experiences had in old countries. The energy and

plucky of California will soon correct the matter.

George P. Marsh, in his "Man and Nature," laid it down as a rule that an effect of irrigation was to concentrate and combine in a few hands, and he wrote an article, which was published as one of our Agricultural Department reports, in which he called

deprecates the introduction of irrigation into the United States, or says that on this account it should be surrounded by great safeguards. He cited instances in Europe, as in the valley of the Po, where the tendency of irrigation had been to perpetuate small farms and bring the lands into the hands of a few of the nobility. He cited but one country where the reverse had been the rule, which was in the south and east of Spain, and pointed out the reason, as he conceived it, that in south and southeastern Spain the ownership of the water went with the land and was inseparable from it, as in our Mexican rights. It is a fact that where the ownership of water goes with the land, it prevents centering of land owned in into few hands, after that ownership is once divided among many persons, in irrigated regions. But Mr. Marsh overlooked one thing in predicting harm in our country; that is, that it will be many years before we will get such a surplus of poor as to bring about the result he feared. In California, the effect of irrigation has not been to center the land in the hands of a few. On the contrary, the tendency has been just the other way. When irrigation was introduced it became possible for small land holders to live. In Fresno county there are many people making a living for a family, each on a acres of irrigated land, and the county is divided into 20 and 40-acre tracts and owned in that way. In San Bernardino the same state of things prevails. Before irrigation, those lands were owned in large tracts, and it was not an uncommon thing for one owner to have 10,000 to 2,000 acres of land. So that the rule in California, where is the effect of irrigation, is to divide land holdings into small tracts, and in this respect, also, irrigation is a blessing to the country. It enables large owners to cut up their lands and sell out to the many. Land values have advanced from $1.25 in this great valley to $50, $150 and even $250 per acre, simply by attaching to the land the right to take on new water paying an additional annual rental; in the southern portion of the State, they have advanced from $5 and $10 to $300 an even $400 an acre, where the land has the right to water; and many calculations have been made and examples cited by intelligent and prominent people, to show that good orange land or good raisin-grape land with sufficient water supply is well worth $1,000 an acre. Water rights run up proportionately in value. A miner's stream flowing an inch of water—an amount that will flow through an inch square opening under four inches of pressure—in the

southern part of the State, as he is at values ranging from $500 to $5000. Such a title stream has been sold hands at $5000, and not at known prices either. In the interior prices are much less, being from about a quarter to a tenth of those in the southern part of the State.

[illegible] one fourth of the United States requires irrigation. When I say this, I mean that fully one fourth the climatic area of our country requires irrigation, in order to support such a population as, for instance, Indiana has. The irrigated regions of fairly adequate productiveness of from 640 to 320 people to the square mile, of south France, for instance, has 150 to 250 people to the square mile, of northeast Spain, from 200 to 300. When we have 40 to 80 to the square mile in agricultural regions we think we have a great population

[illegible] one person, an average of more than 15 to 20 people per square mile. Irrigated land will support as many as any other portion of the country—reasonably it will support 200 to the square mile. I have no doubt that the population will run up to two or three hundred [illegible] per square mile, and [illegible] areas to accommodate [illegible] people. [illegible] the water supply from the Missouri to the Pacific [illegible] water of water. And why not? It has been done [illegible] force. Simply for the reason that there is a lack of knowledge of what can be done and a lack of organization and capital to carry out the enterprises.

The government has recently placed at the disposal of the United States Geological Survey an appropriation for the investigation of irrigation, the cost of irrigation works, and the best methods for irrigation [illegible] the use of water. It is one of the wisest things [illegible] ever done by the government in the subject. The time will come when the cost of all would have been forced upon the [illegible] the value of preparing for that time and of the [illegible]

ROUND ABOUT ASHEVILLE

By Bailey Wood

A broken strip of mountain land in the heart of the South Carolina upcountry in which for one hundred years, its length is forty miles from north to south and its width ten to twenty miles. At its southern gate the French Broad river enters, through the Lovely Gap the same river flows out, augmented by the many streams of its extensive watershed.

From these waters down the ages came more or less gentle slopes to the surrounding heights and that surface, but it now shows, will make the region a very garden, marked by the genius of man and great natural beauty that ever draws more visitors, as the rivers first made their channels, and then the valleys for which the waters gathered the ground, and two of peaks were then scattered. It is now the view from these points of view from which the people of the surface that makes a glance to the world of a geographic conflict to which has long since passed away.

Between the mountains and the plain between the rivers of the French Broad and Swannanoa rivers, now flowing 2000 feet above the level, and at the foot of the Beaucatcher Mountain toward which the ground rises gently. The point to be [illegible] large city, being far from the [illegible] one of the [illegible] and [illegible] on roads from north, south, east, and west. The Asheville business [illegible] large before railroads were projected, and [illegible] of the old turnpikes. It was then the center of western North Carolina, in the west of the county of Buncombe, and was therefore appropriately the seat of the district federal court. A May session of the court [illegible] when I rode up the [illegible] several [illegible] known to me were on trial, and the town street was [illegible] with stalwart mountaineers in [illegible] attorneys, [illegible] horses were hitched at every available rack and fence, and horse

trading was active. Whiskey was on trial at other bars than that of the court, and the long rifle, powder-horn and pouch had not been left in the mountains. To a "furriner-foot" (who had the day before been mistaken for a militiaman or a revenue officer) the attentions of the crowd were not reassuring.

The general opinion was, I felt, akin to that long afterward expressed by transmontane lyrics: "It air an awful thing for a man by accident," and I stood but a very short time in Asheville.

Riding away toward the eastern, I recovered the city plan without seeing that it had had a mountainous nurture. I noted the many gullies, and I set in the malleable detritus the wide level from which they were carved. That the broader fact should be observed by the many lesser ones is no rare experience, and perhaps there is no class of observations of which this has been more generally true than of those involved in landscape study. But when once the Asheville plan has been recognized, it can never again be ignored. It enters into every view, until all enjoyment of beauty and all criticism of change in its conditions which is determined topographic forms. Seated in the mountains one can get at distances of wooded level, rarely in the foreground so wide a gent proportionate to its setting, all about Asheville, save mouths with glimpses of river and valley, broken in upon beyond reach of woodland where it stretches away to the blue mountains. The even ridges form natural roadways, and on arriving one of these crests and looking upon the stream for across two parts and up to the heights. And to this set of impressions a story, the [illegible] plan is a fitting and comprehensive of the time moment phrase, "the everlasting hills." This plan was a fine [illegible] of how to use the [illegible] of economy; it [illegible] those [illegible] of changes. What were the original roads? In what manner have they changed? Let us take new out of certain earlier facts before suggest by an answer. Of the mountains which were the Asheville heights, the Bear Ridge on the east and the Pisgah chain on the west are the two important ranges. The first forms a divide between the tributaries of the French Broad and those of the Gulf of Mexico, and the streams which flow westward from it all pass through the Pisgah chain. It was not impossible to suppose that the roads on the former side found through the lower of the two ranges, but they do not. The Bear Ridge is an irregular, discontinuous elevation but little

over 4000 feet above the sea; the Unaka mountains form a massive chain from 5000 to 6500 feet in height. That streams should thus flow through mountains higher than their source was once explained by the assumption that they found passage through rents produced by earthquakes; but that vague guess marked the early and insufficient appreciation of the power of streams as channel cutters, and it has passed discredited into the history of our knowledge of valley formation. That rivers carve out the deepest cañons, as well as the broadest valleys, is now a truism which we must accept in framing hypotheses to account for the courses of the French Broad and other similar streams. Moreover, since waters from a lower Blue Ridge could never of their own impulse have flowed over the higher Unakas, we are brought to the question, was the Blue Ridge once the higher, or have streams working on the western slope of the Unaka range, when it was a main divide, worn it through from west to east, capturing all that broad watershed between the two mountain ranges? Either hypothesis is within the possibility of well established river action, and both suggest the possibility of infinite change in mountain forms and river systems. Without attempting here to discriminate between these two hypotheses, for which a broader foundation of facts is needed, let us look at the channel of the French Broad below Asheville, in the river's course through the range that is higher than its source. Descending from the old plain into the river's ravine, we at once lose all extended views and are closely shut in by wooded slopes and rocky bluffs. The river falls the more rapidly as we descend, and its tributaries leap to join it, the railroad scarce finding room between the rocks and the brawling current. The way is into a rugged and inhospitable gorge whose walls rise at last on either hand [illegible] to mountains that culminate some thirty miles [illegible] Asheville. At Mountain Island the waters dash [illegible] over a ledge of conglomerate and break out from a long series of rapids into the deep water above Hot Springs. Beyond the broad cove in which the springs occur, the valley, though narrow still, is wider and bottom lands appear. This is the water gap of the French Broad through the Unakas. In our rapid progress, the river seemed a tossing torrent; but had we passed down other streams of similar course, we should have found them even more turbulent, their channels even more sharply carved in the hard rocks. On Pigeon river there are many [illegible] of polished

quartzite, and on the Nantahala river a V-shaped gorge some eight miles long is terraced where the ledges of quartzite are horizontal and is turreted with fantastic forms where the strata are vertical. Where the river valleys are of this sharp cut character in high mountains, the abrupt [illegible]

The Alpine tourist or the mountaineer of the Sierras would expect to come from these cañons to rugged crests or to narrow precipitous peaks. But how different from the heights of the Jungfrau are the "balds" of the Unakas! Like the ice-worn granite domes of New England, the massive balds present a rounded profile against the sky. Although composed of the hardest rock, they yet resemble in their contours the low relief of a limestone area. Broad, even surfaces, on which rocky outcrops are few and over which a scrub oak growth, suggest rather that we are wandering over a plain than on a great mountain; yet you may sweep the horizon and fix [illegible] place. The view is often very beautiful, if unfamiliar, but grand. No crags tower sky-ward, but many domes rise nearly to the same height, and those like these slopes are steepest toward the base. The valleys and [illegible] characters they usually bear, the former are dark and forest-clad, while the latter are broad and bright with softened form. Laboriously [illegible] are on the heights, only pasturage trees are there, which pay up on these treasured [illegible].

These forms of form are not local, they are general. All the groups of [illegible] mountains, where the [illegible] stream formation, whether [illegible] Bald Mountains, are but examples of a common mountain form common throughout the range.

The [illegible] chain presents two peculiar facts for our [illegible]; it is cut through by streams [illegible] and the [illegible] elevations are convex upward not down ward.

If we follow our river's course beyond the Cumberland gate the valley of East Tennessee we shall see. And the channel deeply cut; here as if there bottom lands appear, now on one side, now on the other, but the banks are more often steep slopes or perpendicular cliffs from sixty to one hundred feet high. The creeks and brooks meander with moderate fall through the undulating sur

face of the valley, but they may [illegible] by a recurrence of less abrupt [illegible] to the main rivers. It is thus evident that the [illegible] must keep pace with the rivers in planation, and [illegible] active war [illegible] to sink below the average of general degradation [illegible] would diminish [illegible] relative height of mountains to that of contiguous [illegible] ness [illegible] of the contiguous streams.

If from topographic forms we turn to consider the materials, the rocks of which they are composed, we shall find a general [illegible] of relation between relative elevation and rock structure. Thus the great valley of East Tennessee has a general surface [illegible] from the mean height of the Unakas to an area of easily soluble, often soft calcareous rocks, which the [illegible] consist of [illegible] the Unakas the surface is again lower, and where the [illegible] valley, Lake Bluff Range, here rises, the feldspathic gneisses and [illegible] schists are, relatively speaking, easily soluble, and [illegible] percent. What is thus known to be true in detail, as well [illegible] of a mountain [illegible] or a mountainous [illegible] it [illegible] as forms a great or less elevation above the surface of the [illegible] ness, where a more soluble, less coherent stratum crops out [illegible] the mountain mass, a hollow, a cove, corresponds to it. The [illegible] valley ranges, each mountain is low or not conspicuous [illegible] of mountains above the French Broad valley at Hot Springs [illegible] Tuckaleechee Cove beneath the lofty Smoky mountains, is a fair illustration.

But adequate [illegible] mere ability to resist, is not adequate [illegible] to mountains, but is rock-softness [illegible] to the formation of valleys. The passive attitude of the [illegible] applies a force, that is resisted, and the very terms in which [illegible] must [illegible] represent [illegible] agent would [illegible] declare as, evidence, resistibility. These are terms [illegible] of resistance to a force applied to wear away, to excavate, as flowing water wears by virtue of the sediment it carries and [illegible] Having what we take the relative [illegible] of [illegible] to [illegible] And it is by the [illegible] and abnormal [illegible] of what that not only causes are carved but even mountains [illegible] reduced to [illegible] type.

If we designate this process by the word "degradation," it follows from the relation of resistance to elevation in the region under discussion that we may say: The Appalachians are mountains of differential degradation; that is, heights remain where

the rocks have been most energetically acted on, valleys are started where the action of water has been most effective.

In order that the process of degradation may go on it is essential that it must remain somewhat raised above the sea, and since the process is a never-ceasing one while streams have sufficient fall to carry sediment, it follows that, given time enough, every land surface must be degraded to a sloping plain, to what I have called a base level.

With these ideas of mountain genesis and waste, let us consider some phases of denudation in relation to topographic forms; and in so doing we cannot do better than to use the terms employed by Prof. Wm. M. Davis.

When a land surface rises from sea level the stream system which at once develops sets the task of carrying back to the sea all that stands above it. According to the amount of this allotted work that streams have accomplished, they may be said to be young, mature or aged, and if, their task once nearly accomplished, another uplift raise more material to be carried off, they may be said to be renewed. These terms apply equally to the land surface, and each period of development is characterized by certain topographic forms.

In youth simple stream systems rank in steep walled canons are separated by broad areas of surface unaffected by drainage. In maturity complex stream systems extend branches up to every part of the surface; steep slopes, sharp divides, pyramidal peaks express the rapidity with which every part of the surface is attacked.

In old age the gently rolling surface is traversed by many quiet flowing streams. The hills are gone, the plateaus are rounded, the contours reduced. In the first case the forms are the result of erosion; in the second of deposit, it may be by folding. If the rocky surface into the lakes and arches. During maturity the process of retrogressive erosion, by which a stream cuts back into the watershed of a less powerful adjacent stream, adjusts the channels to the strength of soft rocks and leaves the harder strata as ridges. In old age to a greater or less degree complete and only the hardest rocks remain as low relief.

Suppose that an aged surface of this nature be revived: the rivers hitherto flowing quietly on broad plains will find their fall increased in their lower courses; their channels

rapidly become cañons, and the revived phase will retreat up stream in the same manner that the cañons of youth extended back into the first uplifted mass. If the area of soft rocks be bounded by a considerable mass of very hard rocks, it is conceivable that a second phase of age, a base level, might creep over the valley while yet the summits of the first old age remained unattacked, and should perchance several succeed revival the record of the last uplift might be read in sharp-cut channels of the great rivers, while the forms of each preceding phase led like steps to the still surviving domes of that earliest old age.

Is there aught in these speculations to fit our facts? I think there is. We have seen that our mountains and valleys are the result of differential degradation, and that this is not only broadly true but true in detail also. This is evidence that streams have been long at work adjusting their channels; they have passed through the period of maturity.

We have climbed to the summits of the Balsams and found them composed of rocks as hard as those from which the pinnacle of the Matterhorn is chiseled; but we see them gently sloping as a plain. These summits are very, very old.

We have recognized that dissected plain, the level of the Asheville amphitheatre, now 2,250 feet above the sea; it was a surface produced by subaerial erosion, and as such it is evidence of the fact that the French Broad River, and each of its tributaries as drain this area, at one time completed their work upon it, reached a base level. That they should have accomplished this the level of discharge of the sculpturing streams must have been constant during a long period, a condition which implies either that the fall from the Asheville plain to the ocean was then much less than it now is, or that [illegible] the French Broad was held by a natural dam, where it [illegible].

If we should find that other rivers of this region have carved the forms of age upon the surfaces of their [illegible] valleys, and there is now some evidence of this, and at but [illegible] we must appeal to the more general cause of base level [illegible], accept the conclusion that the land stood lower [illegible] ocean than it now does. Furthermore, we have traversed the ravines which the streams have cut in this ancient plain, and we may note on the accompanying atlas sheet that the branches extend back into every part of it; the ravines themselves prove that the level of discharge has been lowered, the streams have

been revived, and the wide ramifications of the brooks in the characteristic of approaching maturity.

We have also marveled at the topography of the valley and have found the rivers a wide or deep-cut maple chance [illegible] are young, and the numerous streams working on an [illegible] surface that is very sensitive to processes of degradation.

The minor stream systems are very intricate and apparently mature, but they have not yet destroyed the evidence of a general level to which the whole limestone area was once reduced but which now is represented by many elevations that approach 1,000 feet above the sea. Here then in the valley are young river channels, mature stream systems and faint traces of an early base level, all of them more recent than the Ashley base level, which is in turn less ancient than the deeper-like summits of the Unakas.

What history can we read in these suggestive topographic forms of the river system?

The first step in the evolution of a continent is its elevation above the sea. The geologist tells us that the earliest uplift of the Appalachians began after the close of the Carboniferous period was preceded or accompanied by a folding of the earth's crust into mountains more [illegible] upon [illegible] Where they [illegible] best the geologist may infer from present structure and the outcrops of the oldest rocks; but the facts for this inference are not yet all gathered and it can only be said that the heights of that ancient topography were probably as great over the valley of Tennessee as over the Unaka chain. The positions of rivers were determined by the relations of the arches to each other and, as they were in a general way parallel, extending from northeast to southwest, we know that the rivers too had northeast-and-southwest courses. From that first drainage system the Tennessee river, as far down as Chattanooga, is directly derived, and when the geologic structure of North Carolina and East Tennessee is known, we may be able to trace the steps of adjustment by which the many waters have been concentrated to form that great river. At present we cannot sketch the details, but we know that it was a long process and that it was accompanied by a change in the *position* of the mountain ranges. The first mountains were [illegible] but they [illegible] rapidly, they [illegible] but survived because they had

...not been worn down. A topography of differential uplift gave place to one of different degradation. And to the latter the diversified "habit" of the Pocono outcrops—those massive masses of sandstone, pudding-stone and coarse conglomerate now left by vanishing waters, they are covered with a mantle of residual soil, the product of decomposition, and they are [illegible] steep sides of a surface all of which has yielded to degradation. [illegible] move [illegible] In time the streams will cut back and carve jagged peaks from the ridges, but about [illegible] on these heights my thought has turned to the questions they represent—the rest I know that we [illegible]. And then my thought has leaped from the Big Bend out on a gently sloping [illegible] which covered the many domes of nearly equal height now stretched away to meet us—the low sea [illegible] level of the sea. Last, I remember, was the first base level [illegible] plain of which we have any evidence in the Appalachians—the one [illegible] that [illegible] our present valleys have been eroded. The [illegible] time that mountains must then have been [illegible] feet less than [illegible] now, and the highest [illegible] were probably not more than [illegible] feet above the sea. Then was perhaps a period of constant [illegible] between sea and land, but it was succeeded by one during which [illegible] slowly rose. The rivers, which had probably [illegible] nearly their present courses, were revived; the [illegible] tributaries stepped in rapids and fell back into [illegible] of base level. The region continued to [illegible] a portion long enough to permit the essential features of the mountains to [illegible] of today, since at [illegible] relations between [illegible] permanently established somewhere, and the [illegible] streams [illegible] probably other rivers made record of the [illegible] plain like that about Asheville. Again the land rose slowly; again [illegible] rivers, and rivers, working always from the sea, cut backward [illegible] curves a base-level in the limestones of the great valley; but before that level reached [illegible] through all the [illegible] in the [illegible] the continent was raised to its present elevation, the [illegible] remained suspended in the intervening [illegible] between them and the rivers which they began to cut the [illegible] many [illegible].

And we [illegible] step by step from these latest sharply cut [illegible] back up stream through the chapters of erosion [illegible] and stages of an early [illegible] age? Let us sum up the history we have traced. There is reason to believe that:

1st. The consequent topography of the earliest Appalachian uplift was entirely removed during a prolonged period of erosion and was replaced by a relief of differential degradation.

3. The height of the Caucasus represents the heights of that mountain approach to a knife-edge.

4. The topography of the region has been revised by a geologist, though not necessarily uniformitarian, divided by two intervals of rest, during the first of these the Aegean Sea was formed, and the second [illegible] alone was reduced.

5. The latest movement of the uplift has been, on a geological epoch age, quite recent, and the rivers have accomplished but a small part of their new task.

These contours are reached on the observation of a single range of facts in one district, they must be compared with the results of [illegible] examination of the mountains in the depression of the coastal plain, and in the topography of other areas.

The history of the Appalachians is written in every river system and on every mountain ridge, but its characters are illegible for each are only by the application of [illegible] knowledge, to whose every learner may contribute, is extended over the entire region. And we know none always the whole story.

A TRIP TO PANAMA AND DARIEN

By Richard T. Greene

The Government of the United States of Colombia in the act of concession to the Panama Canal Company provided that it should give to the latter "*gratuitamente el area de tierra baldia que la misma compañia necesite*" 5,000,000 hectares of land.

Some of the conditions attached to the grant were, that the land should be selected within certain limits and surveyed by the Canal Company; that a topographical map should be made of the areas surveyed and that an amount equal to that surveyed for the canal should also be surveyed for the benefit of the Colombian government. It was also further agreed that it would not be necessary to complete the canal before any of the land should be [illegible] but that it would be given at different times in amounts proportional to the amount of work accomplished.

There existed the understanding that one-half of the work on the canal had been finished and that the company was consequently entitled to 2,500,000 hectares of land, upon the completion of the necessary surveys, etc.

The land was eventually chosen partly in Darien and partly in Chiriqui as follows:

In Darien three lots, one between the Pava and Mucha rivers, one between the Maria and Pirri rivers, the two amounting to 500,000 hectares, and one lot of 25,000 hectares between the Tapa and Pucro rivers.

In Chiriqui, which is a Province of Panama just east of Costa Rica, two lots were chosen amounting to 125,000 hectares, one between the Sierpe and Rabalo rivers, and the other between the Catabe la and San Pedro rivers.

The Canal Company wanted the title to the land in order that it might be used as collateral security in bolstering up the finances of the corporation, and the Colombian government was doubtless very willing to let the Canal Company have this amount or as much more as was wanted, both parties being equally aware of the valueless character of the land for any practical purposes.

My services were engaged in 1885 in connection with the contro-

natural work incident to the survey of these ports and it was intended that I should visit both Darien and China, but the contract term expired also at the time of the completion of the work in Darien, which was taken up first and it was deemed prudent for various reasons, the chief of them being the unhealthiness of the country at that season of the year, about the middle of April, not to remain longer on the Isthmus. If it had been possible to work as expeditiously as in this country there would have been ample time to have completed the necessary astronomical work for both surveys, and without understanding men and methods peculiar to a tropical country I started out with this expectation, but soon found out that any efforts looking towards expediting any part of our duties were not only useless but were detrimentally reactive upon the person putting forward such efforts. Thus it was nearly the first of March before I reached Darien, having sailed from New York a month previously. Passage was had from Panama to Da[illegible] in a steamer chartered for the purpose. Sailing across the bay of Panama and entering the Tuyra River at Boca Chica, we ascended the river as far as the village Real de Santa Maria. At this point the steamer was abandoned and further transportation was had in canoes.

Darien is a province of the State of Panama and its boundaries are as given by Lieut. Selfridge in his comprehensive work on "Projects of Interoceanic Communication," are as follows: "The Atlantic coast line is included between Point San Blas and Cape Tiburon; that of the Pacific extends from the mouth of the Bayano to Point Arenas. The eastern boundary is the main Cordilleras in its westerly course across the Isthmus from a position of close proximity to the Pacific, near Point Arenas, to a similar position near Tiburon, on the Atlantic. The watershed of the Madungandi and Mammoni Mayano determine its western limit."

The Darien bank as seen from the Atlantic side presents to the view an apparently solid ridge of mountains, although there are in fact many low passes which are [illegible]

The [illegible] rivers have their rise in the Atlantic, as the rivers on which there are a great many on this side, passing promptly to the sea. On the Pacific side the rivers have a much longer distance to flow before reaching the sea, and the territory bordering the ocean is now and swampy. The Tuyra, mouth of the Bayano River is nearly fifty miles from its mouth, and on this river as I

many of its tributaries one can travel many miles and before ground sufficiently raised to admit upon can be found The vegetation within this low lying area is thick and closely matted together, and this fact taken in connection with [illegible] water of the ground, makes travel on foot through any portion of [illegible] Therefore the various rivers, which form a system and penetrate everywhere are the natural highways of the country. The chief rivers on the Pacific side are the Tuira and Bayano with their numerous tributaries and on the Atlantic watershed is the Atrato

A peculiarity noticed at Real de Santa Maria, which is at the mouth of the Pyrria and Tuira rivers and at which point the [illegible] rise of twelve or fifteen feet, was that at low tide it was impossible to enter the mouth of the Pyrria with a boat, while two or three miles up the stream there was always a good supply of running water and at double that distance it became a mountain torrent

Outside of the swampy area the character of the country is rough and mountainous The valleys are narrow and the ridges unusually sharp, the natural result of a great rainfall The hills are able to resist the ever varied wasting effort of the constant trickling of descending water only by the thick mantle of dense matted vegetation, and were it not for this protection the many months of continuous torrential rain would long ago have produced a leveling effect that would have made unnecessary the various attempts of man to pierce the Isthmian mountains and form an artificial strait

The ridges are sometimes level for a short distance, but are generally broken and are made up of a succession of well rounded peaks These peaks are always completely covered with trees at least from the top of the highest of them it is impossible to get a view of the surrounding country The highest peak studied was about 2,000 feet above sea level and the highest peak in Darien is Mt Pirria which is between three and four thousand

Darien has been the scene of a great deal of surveying and exploration, from the first Spanish explorers in 1509, coasted along its shores, hoping to find a strait connecting the two oceans, up to the present time. Balboa, in 1513, discovered the Pacific by crossing the Darien mountains from Caledonia Bay. This discovery taken in connection with the broad indentations of the [illegible] and [illegible] led to the belief in the exist

edge of a strait, and the entire coast on each side of the new world was diligently searched. The Cabots, Pedro de Leon and Cortes interpreted them one and all in this search and it was not until about 1552 that all expectations of finding the strait were abandoned. The idea of a direct natural communication between the oceans being thus disposed of, the question of an artificial junction arose, and in 1551 a Spanish historian recommended to Philip II. of Spain the desirability of an attempt to join the oceans by identically the same routes by which the attention of the whole civilized portion of the world is now being drawn, that is, Tehauntepec, Nicaragua and Panama. From this time up to the commencement of the work of the Isthmian expeditions sent out by the United States, and which lasted from 1870 to 1875, but little geographical knowledge relative to Darien was obtained. The United States government undoubtedly did a great amount of valuable exploration and surveying, and whose the names of Strain, Truxton, Selfridge and Lull will always be held in [illegible] what they accomplished in this direction, still it is to be regretted that with all the resources at their command they did not make a complete map of the country. And just here I want to bring forward the suggestion that all that has been accomplished and more, could have been accomplished if the various explorers and known, or practically attained, a fact that my own experience and that of other topographers, in this country and Darien, has proved upon me; and that is, that it is easier in a rough and mountainous country to travel on the ridge than in the valley. In Darien they were looking for a low pass that a flood line and this was what should have first been sought, properly. Having found the low passes the valleys of the streams draining therefrom could have then been examined, and thus an accurate [illegible] plan followed by the [illegible] with the hope of finding a suitable pass. The pass might be found or it might not, and if not, so much labor as far as the direct solution of the problem was concerned was lost. A pass of low altitude was of primary importance and should have been sought for in an exhaustive way.

Lindsley said in substance, "Do not waste your time in running experimental lines across. Send out a party fully equipped with [illegible] to explore the [illegible] for the purpose of the Isthmus, for this [illegible] a project to connect the

cal, geometrical and geological conditions of the dam that obstructs the intercourse of commerce of the world." But strange to say this plan suggested by such an eminent authority as Humboldt and [illegible] commended by common sense has never been fol- lo[illegible] [illegible] money that has been spent and the lives lost in explorations in Darien, there is not sufficient data collected to prove conclusively that there does not now exist some route for an interoceanic canal that possesses merits superior to any at present known. It is true the dividing ridge would be difficult to follow on account of the great number of confusing spurs, but I think I am safe in saying that starting from the south end of the main ridge at Culebra pass on the Isthmus of Panama, the dividing ridge continuing to the pass at the head waters of the Atrato could be extensively followed and studied with as much facility as compared with the Tuyra or Atrato rivers, embracing with them their respective tributaries.

I traveled over some of the high dividing ridges in Darien, and did not find that progress was at all difficult, and especially noted the fact of the absence of tangled undergrowth and matted vines which is so characteristic of the Darien forests generally.

Now a few words about the inhabitants of Panama and Darien; and in referring to these I mean the native inhabitants and not the heterogeneous gathering of all nationalities that were attracted by the Panama Canal.

In Central and South America, as in North America, the aboriginal inhabitant was the Indian. When the Spaniards first attempted to colonize Darien they were met and resisted by the native Indian just as our forefathers were in Virginia and Massachusetts, and as with us so in Panama and Darien the Indians have been driven back by degrees from the shores of both oceans until now they are found only in the far interior.

They resemble our Indians in appearance, but are smaller. They are averse to manual labor and live almost entirely by hunting and fishing, although they sometimes have small plantations of plantains, bananas, oranges and lemons. The Spaniards in settling in the new country brought very few women with them and the Colombian of to-day is the result of the admixture of the Indian and Spanish blood, and has many of the characteristics of each race. In addition to the Indian and Colombian there are in Panama and Darien a comparatively large number of negroes, who were originally imported as slaves by the early Spaniards,

and who now constitute by far the larger portion of the [illegible] ants of Darien, being found in many villages along the valleys of the larger streams. In contrast to the Colombian and Indian they are large in stature and make excellent laborers.

The principal villages in Darien, as Yavisa, Pinogana and Real de Sta Maria, are inhabited exclusively by these negroes, with the [illegible] of a Spanish judge in each, who exercises great [illegible]. Besides being a judge in civil and criminal cases, he practically controls everything in his particular village, as all contracts for labor are negotiated with him and settlement for services made through him.

Upon reaching Darien the first work assigned me was the survey and exploration of the Pirri river. This survey was made for two purposes: primarily, to determine if any of the country bordering upon it was of a sufficiently desirable character to be included within the grant, and secondly, to secure data for the general topographical map. My instructions were to proceed as far south as latitude 7° 40'. The ascent of the river was made in canoes until the frequency of rapids made it necessary to abandon them, and then the journey was continued on foot, generally wading in the middle of the stream, as the undergrowth was too thick to admit of progress along the banks. Sometimes the water was very shallow; at other times, where it had been backed up by dams of porphyritic rock, it reached above the waist, and near the head of the journey, where the river ran between vertical walls of great height, it was necessary to swim in order to get beyond the cañon.

The survey of this river was satisfactorily accomplished in about a week. The method adopted for this survey was to take compass bearings and to estimate distances. The [illegible] and distances were plotted as they were taken in order that the topographical and other features could be readily sketched in connection with them. To check and control this work, observations were taken every day at noon with a sextant, on the sun [illegible], and at night observations at times of stars were obtained when possible.

Later a number of rivers were surveyed—the Maria, Tuquesa, Yape and other tributaries of the Tuyra. When it was found that a sufficiently correct idea of the country for topographical purposes could not be obtained by simply meandering the water courses, a number of trails were cut through the forest from stream

to attempt, and where two streams thus connected were tributaries of a common river, and of which had been previously surveyed, a closed figure was of course, an adjustment for errors of closure made, and by passing together the topographical data obtained by the four lines, there was generally found to be sufficient information to give a satisfactory sketch of course of the intervening country.

After a number of trials we became familiar with more or less accuracy in this way, it was thought desirable that a large portion of the great basin tributary to the Gulf of Darien and lying on the right bank of the Atrato river and including portions of the river where the boundaries of two of its tributaries, the Bia Bajo and the Atrato proper, would be the boundaries of the tract. The lines of the base courses approximately parallel to each other and at right angles to the Bia Bajo, and these streams were also chosen as boundaries to one so that the tract would have two more natural boundaries, and the fourth and closing boundary was to be a straight line from a point on the Cape to the Pacific, so located as to include within the four boundaries an area approximately equal to the amount of the grant, which in this particular case was 46,000 hectares. The problem then presented was given the rivers for three boundaries of a figure to establish a fourth so as actually to complete the figure in such a way that it would contain a given area, and also to procure data for a topographical map of the country surveyed.

The survey was put under my direction and I was instructed to proceed to a point on the Pacific coast between the Bia Bajo and the Rio Tuira, near the mouth of the latter, for the purpose of establishing a base line. Leaving Boca de Sta. Maria on the evening of March 15th, with a force of twelve chasers and about thirty native laborers, we reached the site for the camp in two days. After landing everything, the work of clearing away trees and underbrush over an area sufficiently large for the camp was commenced. The men worked with axes and machetes, and soon the forest was felled and left here a semi-circular space facing the river.

Two houses were needed and without saw, nail or hammer the construction was commenced and prosecuted rapidly. Straight trees about six inches in diameter and twenty feet long were cut and planted vertically in holes dug out with the machete, and

horizontal pieces of a smaller diameter were securely fastened on with bejuco tough strips of bark, and thus a square or oblong frame was fashioned. The horizontal pieces were placed at a distance of about three feet from the ground, on which a flooring was eventually laid, and at the top of the frame where the slope of the roof began. On the big posts other poles were laid and fastened across and lengthwise, and on these the green wood was making the skeleton of the roof. The latter was made very steep for better protection against the rain. After the ridge pole was put in position other smaller poles were fastened on parallel and perpendicular to it so that the whole roof was divided up into squares, and it was finally completed by weaving in thick bunches of palm and other leaves in such a way as to make it thoroughly water-proof. For our purpose no partitions on the sides of the structure other than the project ng eaves was considered necessary. A few of poles laid very close together were put in one house, the one used for our kitchen purposes, and in the other a table for eating, writing, drawing, etc., was made. Thus in two or three days the place was made thoroughly habitable, and men were started to see that the grounds, etc., were always kept thoroughly clean and dry as a good sanitary condition, a very necessary precaution in a tropical country. The forest afforded game, the river an abundance of fish, bananas, oranges, limes and pineapples were easily procured from the natives, who also furnished material for a poultry yard, and thus while locating at camp Cupica, which I do it was on a picturesque spot over which two swift flowing rivers, with good drinking water, a commissary department well stocked, a French cook who would have himself credit anywhere, I must not but think that spectacular pictures of life in Darien had been too somberly drawn, and that where so much suffering and sickness had prevailed among the early explorers it was because they had gone there not properly equipped, and because carried away with ambitious enthusiasm their actions rather than their better judgment would not have dictated; and that to these causes as much as to the unhealthy condition of the country was due their many hardships. Several days were spent here getting a general knowledge of observations and in mapping out plans for the work. It was decided that the mouths of the Napipi, Cupica and Pucro and other points along these rivers, such as mouths of tributary streams, etc., should be astronomically lo-

cated, that these points should be connected by compass lines, and so that cross lines should be run at various points from the Tape to the Capote and from the Capote to the Pucro. It was further decided that as time was limited it would be impracticable to run out the fourth side of the figure that would contain [illegible] by rough and mountainous, and to follow any straight line would necessarily involve a great amount of laborious cutting and clearing.

Furthermore, in order to know just what direction this line should follow it would be first necessary to make a connected [illegible] survey of the three rivers; to plot this survey and [illegible] and consultation of various starting points to decide on the most available location of the fourth side.

Instead of this it was considered best and sufficient to arbitrarily adopt a certain waterfall on the Rio Tape, the location of which was approximately known from [illegible] and the total length of the compass lines up the Tape with the Pucro and closing the figure. Thus it only became necessary, as far as the boundaries were concerned, to run a line [illegible] the Tape, passing the mouths of the Pucro and Capote to the waterfall above referred to; and to run up the Pucro sufficiently far to be certain that when the work was completed and plotted, a line drawn from the position of the waterfall on the map in such a way as to [illegible] to the desired area would intersect the Pucro at some point within the limit of what had been surveyed. I have not time to go into the details of the various trips by land and water necessary to carry out these plans.

Before starting it was known exactly what was necessary to be done; each assistant engineer had his work clearly mapped out before him, and each one faithfully performed the task allotted to him, so that the whole survey was brought to a successful completion. This brought to a close all the work in Darien, the other tracts having been surveyed before my arrival and consequently the whole expedition returned to Panama, and soon afterwards I returned to this country.

In going to and returning from Darien, I passed twice over the Panama Railroad [illegible] Panama and I have thought that a few remarks on the road might prove of interest to the Geographical Society.

Palmston, herewith is a sketch showing the location of the railroad, canal and tributary drainage, and a profile along the axis of the canal.

The first surveys for the railroad were made in 1849, and it was probably the excitement of the California gold fever that brought about its construction at this particular time. Ground was broken in January, 1850, and the last rail was laid in January, [illegible].

The length of the road is 47.6 miles and it crosses the dividing summit at an elevation of 263 feet above the mean level of the Atlantic ocean. The maximum grade is 60 feet to the mile. Soon after the road was built accurate levels were run to determine the difference, if any, between the Atlantic and Pacific oceans, and it was found that the mean levels were about the same, although there are of course variations owing to local causes, and considerable difference of height at times, owing to differences of tides in the Atlantic and Pacific. At Aspinwall the greatest rise is only 1.6 feet, while at Panama there is at times a difference of over 2[illegible] feet between high and low water. The cost of the railroad was $[illegible].

The existence of the railroad was probably the deciding cause that led Lesseps to the adoption of this location of the proposed canal.

Now that the scheme has practically failed it is very easy to see and appreciate the difficulties that lay in the way of building a canal at this particular place, and it certainly seems that if sound engineering principles had been adopted at least some of these difficulties could have been overcome and properly combatted. The whole scheme, however, from an engineering standpoint seems to have been conducted in the most blundering manner.

Lesseps is a diplomat and financier, but [illegible] engineer. In the construction of the Suez canal, the questions of diplomacy and finance were the most difficult to settle, while the engineering problems were comparatively simple. At Panama the opposite conditions prevailed. Concessions were freely given him by the Colombian government and money freely offered him by the French people, but he never grasped or comprehended the difficulties that nature had placed in his way, and these only seemed to occur to him when they blocked progress in a certain direction. The [illegible]

on the 29th of May, 1879, that the construction of an inter-oceanic canal was possible and that it should be built from the Gulf of Limon to the Bay of Panama.

The Congress and company adopted the following general dimensions: Length, 45.5 miles; depth, 28 feet; width at water line 164 feet, and width at bottom 72 feet.

The route determined upon was about the same as that of the railroad, first following the valleys of the Chagres and Obispo, crossing the divide at Culebra pass and then descending to the Pacific along the course of the Rio Grande. The profile which is reproduced from "Science," shows the state of progress on January 1st, 1888, and the amount of excavation that has been done since that time would make but a slight difference in the appearance of the profile. The portion shown in black is what has been removed above the axis of the canal and represents an expenditure of over $260,000,000 and seven years' labor. The reasons that make the scheme impracticable are briefly these: some of which were known before the work was commenced, and all of which should have been understood.

The first great difficulty was in cutting through the ridge culminating at Culebra where the original surface was 354 feet above the bed of the proposed canal. It was never known what the geological formation of this ridge was until the different strata were laid bare by the workman's pick, and the slope adopted, 1 1/2 to 1, was found to be insufficient in the less compact formations, even at the comparatively shallow depth that was reached, and many and serious landslides were of frequent occurrence.

Another serious difficulty was the disposition of the excavated material, for upon the completion of a sea-level course the channel would naturally drain all the country hitherto tributary to the Chagres and Rio Grande, and any substance not removed to a great distance would eventually be washed back again into the canal. But perhaps the greatest difficulty was in the control of the immense surface drainage. The Chagres river during the dry season is, where it crosses the line of the canal near Gamboa, only about two feet deep and 250 feet wide, but during a flood the depth becomes as much as forty feet, the width 1,500 feet, and the volume of water discharged 100,000 cubic feet per second. The bed of the river is here 42 feet above sea level, or 70 feet above what the bottom of canal would have been. Now add to

than a 40-foot flood and we have a water surface one hundred and ten feet above the bed of the river.

In order to keep this immense volume of water from the canal it was proposed to build a large dam at Gamboa, and to convey the water by an entirely different and artificial route to the Atlantic. It is supposed by those who favor the high-level plan that the Chagres, by a rough measurement shows it to be about 500 square miles. This seems a small total for a large area. But when it is considered that the annual rainfall is about 10 feet, that this rainfall is confined to about one half the year, and that in six extreme wet hours there has been a precipitation of over six inches of rain, some idea of the number of cubic feet of water that finds its way through the Chagres river during the wet season may be formed.

As I said before it was proposed to protect the canal from the waters of the upper Chagres by an immense dam at Gamboa, and for the purpose of conveying the water that crosses the canal Chagres two additional canals or channels were to be constructed on either side of the main canal. This, as the river is very tortuous and the axis of the canal crossed it twenty-five or thirty times, many deviations of the former became necessary. In some places the canal was to occupy the bed of the river and in others it cut across ends leaving the river for its original natural purpose of drainage. The difficulty in retaining the floods in these constructed channels would, of course, be great, especially in view of the cases where the water rushing along the natural channel is suddenly turned at right angles into an artificial one. Thus it is clear that aside from the enormous excavation [illegible] unfinished, it would be practicable to pass ships to the Atlantic at sea-level only by reason of the difficulty in controlling the Chagres and preventing the [illegible]

The canal company finally came to the conclusion that a high-level scheme was impracticable and it was abandoned, and plans were prepared for a lock system. As soon as the project came to be proposed, five miles on each side of the natural level. The summit level was to be 85 feet above sea level and consequently each lock would have a lift of thirty feet. The profile was constructed especially to show the amount remaining to be [illegible]

show the relative amount of completed and uncompleted work along the axis of the canal. To complete the summit cut it is still necessary to excavate 11½ feet, 93 feet having already been excavated, through a horizontal distance of 700 feet. The width of cut at top surface for the required depth at a slope of 1 to 1 would be 750 feet, but as I said before, at this slope landslides were of frequent occurrence and the slope would probably have to be increased to at least 2 to 1.

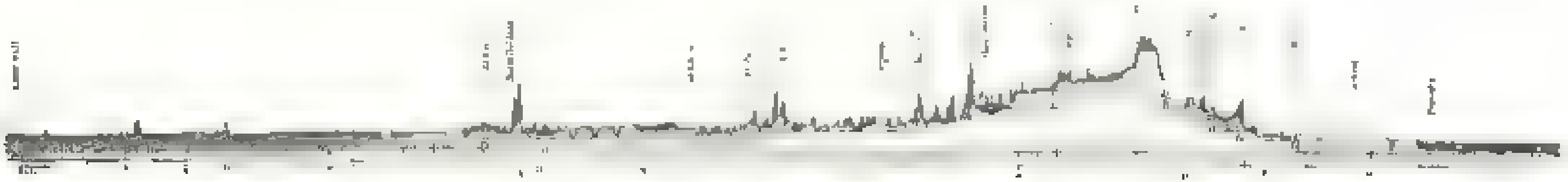
Granting the necessary excavations made, there would be still the problem of the control of the Chagres river and the water supply for the summit level to provide for. At first it was thought that the water supply could be obtained from the storage of the waters of the Chagres and Obispo, but this idea was eventually abandoned, either from a belief in the insufficiency of the water supply during the dry season, or from difficulties in the way of conveying the water to the summit level.

Then it was that the advice of Mr. Eiffel, a noted French engineer, was sought, and after a visit to the Isthmus he proposed that the summit level should be supplied by pumping from the Pacific. A contract was immediately made with Eiffel, who was hereby set all over the world as a man who would move mountains and immediately a positive day, the seventh that had been announced, was fixed for the opening of the great canal.

I do not know just how much work was done towards perfecting the system for pumping, but probably very little was ever accomplished in that direction, as soon after the new scheme was taken up the available funds of the canal company began to be very scarce and there has been since then a general cessation of work all along the line, now to be entirely suspended. From what I have said and from what can be seen from the profile, it will be readily understood that so far as the sea-level project is concerned the amount done is not much more than a scraping of the surface, relatively speaking, and that what has been done is in places where the canal prisms were fewest.

In regard to the lock canal about one-third of the necessary excavations have been made along the axis of the canal, but large portions of the sections, I should imagine, roughly, that probably only one-sixth of the whole amount of work had been accomplished. The question now naturally arises as to what will be the probable future of this great enterprise.

The French people have seen the advantage that under Lesseps in which they had to pay enormous commissions, and it is probable that they will raise any more money to be put in it as a business enterprise until a new and very different set. Should such a with a debt of nearly four hundred millions of dollars, it would be difficult to convince any one that it could ever prove a profitable investment. Nor do I think that any American or English corporation can be organized that could obtain such concessions from Lesseps as would make the canal an inviting field for capitalists, and this my opinion is that the "Compagnie Universelle du Canal Interocéanique de Panama" has practically collapsed, and that the canal will remain, as it is now, the great property in fact of the age.



SKETCH SHOWING LOCATION OF

PANAMA RAIL ROAD, PANAMA CANAL

AND TRIBUTARY DRAINAGE

ENTRANCE TO BLT LANDS RIVER SAN JUAN

ACROSS NICARAGUA WITH TRANSIT AND MACHETE.

By K. E. Isaby

The action of this National Society, with its array of distinguished members, in turning its attention for an hour to a region which has interested the thinker the world for more than three centuries gives me great pleasure and satisfaction.

I propose this evening to tell briefly and briefly upon the natural features of Nicaragua, to note the reasons for the interest which has always centered upon her, to trace the growth of the great project with which her name is inseparably linked, to show you somewhat in detail, the life, work, and surroundings of an engineer with his builders, and finally to show you the result that is to crown the engineer's work in her wide and roaring torrents and fertile valleys.

That portion of Central America now included within the boundaries of our sister republic Nicaragua, was almost from the moment that European eyes looked upon it attracted and charmed the attention of explorers, geographers, great rulers, students, and men of vague and dim far reaching intellect.

From Columbus the long list of famous names which have linked themselves with Nicaragua reaches down through Humboldt, Napoleon III., Ampere, Lull, Menocal and Taylor.

The shores were first seen by European eyes in 1502, when Columbus on his fourth voyage rounded the cape which forms the northeast point of the state, and called it "Gracias a Dios," which name it bears today. Columbus then coasted southward up the eastern shore.

In 1523, Avila penetrated from the Pacific coast of the country to the lakes and the cities of the Indian inhabitants. Previous to this the country was occupied by a numerous population of Aztecs, or nearly allied people, as the quantities of specimens of pottery, god images, and other articles found upon the islands and along the shores of the lakes, prove at present

In 1502 the connection of the lakes with the Caribbean sea was discovered, and during the last half of the eighteenth century a considerable commerce was carried on by this route between Granada on Lake Nicaragua and the ports of Nombre de Dios, Cartagena, Havana and Cadiz.

In 1821 Nicaragua threw off the rule of the mother country and in 1824 formed with her sister Spanish republics a confederation. This confederation was dissolved in 1838, and since then Nicaragua has conducted her own affairs. In point of advancement, financial solidity and stability of government she stands to-day nearly, if not quite, at the head of the Central American republics.

Nicaragua extends over a little more than four degrees each of latitude and longitude, from about N. 11° to N. 15° and from 83° 30' W. to 87° 40' W.

Its longest side is the northern, in a line from the Gulf of Fonseca northeasterly to Cape Gracias a Dios, two hundred ninety miles. From that cape a line to the mouth of the Rio San Juan, the Caribbean coast line is two hundred and fifty miles. Nearly due west across the isthmus to the nearest bay on the Pacific, is one hundred and twenty miles. The Pacific coast line extends thence northwest one hundred and sixty miles.

In point of size Nicaragua stands first among the Central American republics, having an area of 51,660 square miles. It is larger than either the State of New York or Pennsylvania, about the size of Denmark, Belgium, the Netherlands or Switzerland combined, and is one-fourth as large as France or Germany. Its population numbers about 350,000.

The Gulf of Fonseca, at the northern, and San Juan Bay at the southern extremity of the coast line are two of the finest and largest harbors on the Pacific coast of Central America. About midway between them is the fine harbor of Corinto, and there are also several other ports along the coast, at San Juan del Sur, Brito and Tamarindo. On the Caribbean coast are harbors suitable for large vessels at least, but numerous lagoons and lights afford the best of shelter for coasting vessels.

The central portion of Nicaragua is traversed, from north to south, by the main cordillera of the isthmus, which, here greatly reduced in altitude, consists nearly of a continual range of peaks and ridges with an average elevation scarcely exceeding 1,000 feet.

Between this and the Caribbean shore stretches a low-level country, covered with a dense forest, rich in rubber, cedar, mahogany and other woods. It is drained by many large rivers which are fertile in alluvials and yield a profitable harvest of plantains, bananas, oranges, limes, and other tropical fruits.

West of the main [illegible] is a broad valley, [illegible] feet above the level of the sea, which from the Gulf of Fonseca, southeastward to the frontier of Costa Rica. The greater portion of this valley is occupied by two lakes, Managua and Nicaragua. The latter is one hundred and [illegible] miles long by fifty [illegible] nearly three-quarters of which belong to Nicaragua. Islands and bays are large and [illegible] Large islands. Rivers and bays are large and [illegible] Rivers. These lakes, [illegible] the rainfall of the adjacent valleys, drain through the [illegible] San Juan river, which empties into the Caribbean sea. [illegible] surplus [illegible] the Pacific ocean, but this [illegible] most [illegible] of the country.

Between the Pacific and these lakes is a narrow strip of land, [illegible] twelve to thirty miles in width, stretching from the mouth [illegible] Gulf of Fonseca to the [illegible] Lake Nicaragua, and [illegible] the north, to the mouth [illegible] Nicoya, on the south.

The lowest pass in the backbone of the New World, from Behring's Strait to the Straits of Magellan, extends along the San Juan river, [illegible] Lake Nicaragua, [illegible] between Lake Nicaragua and [illegible] the mouth of the river is [illegible] and [illegible] feet above the sea, and forty miles [illegible] the lake.

A [illegible] presents yet another [illegible] physical feature. It [illegible] from the [illegible] mountains of Costa Rica on the south and Honduras on the north, [illegible] average [illegible] seven [illegible] mountain backbone here [illegible] the usual [illegible] the [illegible] northeast Trades. [illegible] with a [illegible] from [illegible] and [illegible] across the Atlantic plains, [illegible] the surface of the lakes into sparkling waves, and then disappear over the Pacific, [illegible] and purify the [illegible] dry [illegible] portion of Central America [illegible] northeast region.

The scenery of the eastern portion of the country is of the [illegible] sameness peculiar to all tropical countries.

In the vicinity of the lakes and between them and the Pacific the eastern mountain [illegible] of the part of Lago [illegible] mountain ranges of Matagalpa and Chontales, the towering turquoise masses of the Costa Rican volcanoes, and the distant blue of the waters of Lagoa de Managua, while beyond [illegible] the sparkle of waters of the lakes, form the eye with scenic delights unsurpassed elsewhere in grandeur, variety and the [illegible] of color.

The productions of the country are numerous despite the fact that its resources are as yet in a great measure undeveloped.

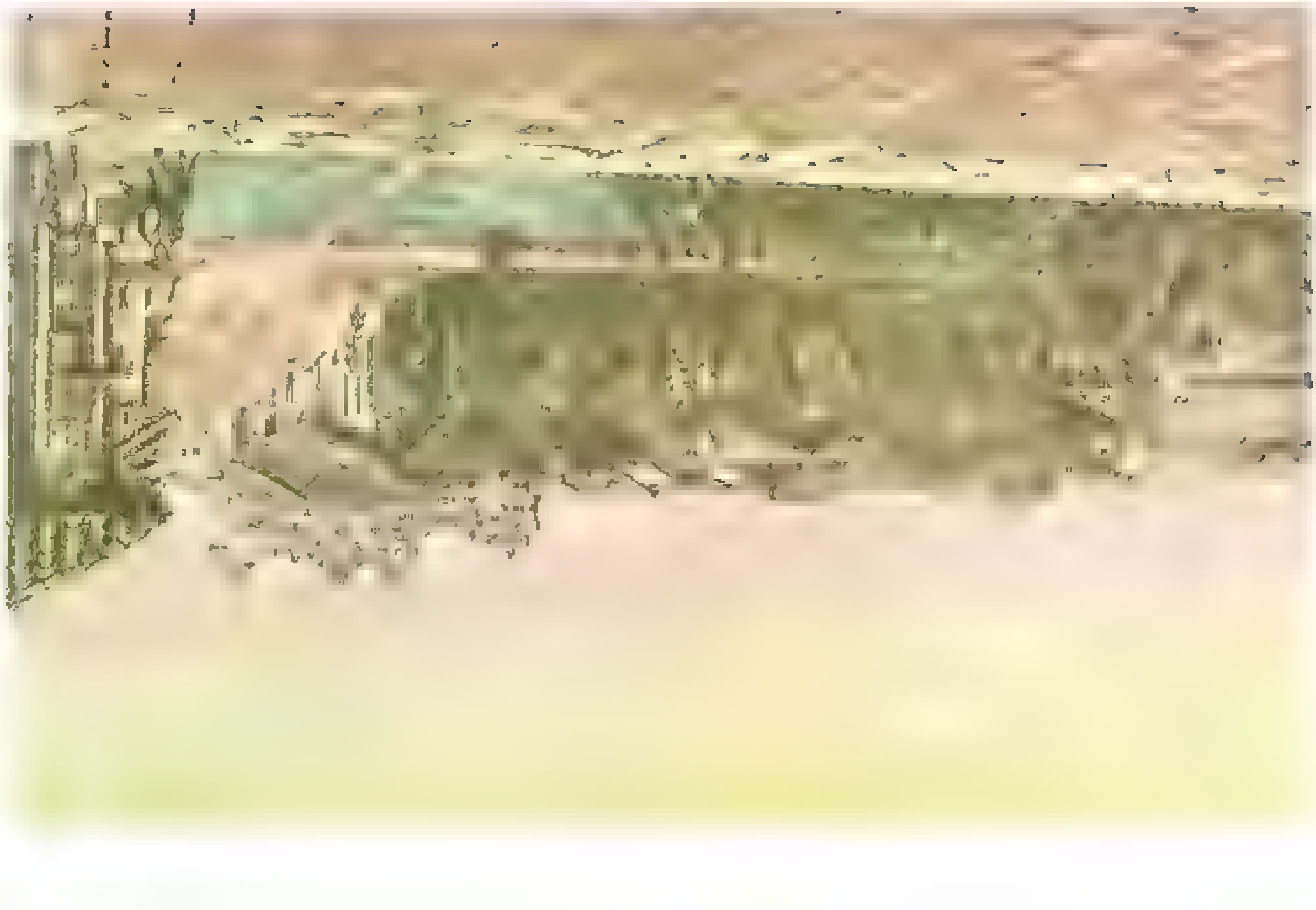
Maize, plantains, beans, rice, potatoes, yuca, and almost every tropical fruit, thrive in abundance. Coffee is grown in large quantities in the hilly region to the northwest. Sugar, tobacco, corn, rice, mango and cacao plantations abound between the lakes and the Pacific; potatoes and wheat thrive in the uplands of Segovia, the Chontales region east of Lake Nicaragua, a great prairie section, supports thousands of head of cattle, and back of this are the gold and silver districts of La Libertad, Juan Aldaz and others.

Numerous trees and plants of medicinal and commercial value are found in the forests. Game is plentiful and of numerous varieties; deer, wild hogs, wild turkey, manatee and tapir; and fish abound in the streams and rivers. The temperature of Managua is equable. The extreme variation, recorded by Chase, was 93° observed near the head of the San Juan in May, 1851.

The southeast trade prevails during the rainy season. October 15, [illegible] or October as a rule, the wind hauls around to southwest and [illegible] remains there for a week or two.

The equatorial cloud belt, following the sun north, [illegible] the spring [illegible] are reaching Nicaragua, and the wet season is shorter the region farther south. The average rainfall, based on the records of nine years, is 64.42 inches. The "trades" blow almost throughout the year. Starting during the dry season and [illegible] during the day; the wind comes from the east-northeast, and blows usually for four to five days, veers, hauling to the east or southeast for a day or two, it calms down, then goes back to northeast and [illegible] again.

The Spanish discoverers of the great Lake Nicaragua, coming upon it from the Pacific, and noting the [illegible] of seas caused



by the action of the wind upon its broad surface, mistook these fluctuations for tides and felt assured that some broad strait connected it with the North Sea. Later, when Machuca had discovered the grand river outlet of the lake, and the restless searching of other explorers in every bay and inlet along both sides of the American Isthmus had extinguished forever the ignis fatuus "secret of the Strait," Gomara pointed this out as one of the most favorable localities for an artificial communication between the North and South Seas.

[illegible]

This survey, which showed the lake of Nicaragua to be only one hundred and seven feet above the sea, and the maximum elevation between the lake and the P[illegible] feet [illegible] answered in a manner that it has never since been positively [illegible].

In 187[illegible], under the administration [illegible] through the unceasing efforts of Ad[illegible] States began a series of systematic surveys of all the routes across the American isthmus from Tehuantepec to the [illegible] waters of the Rio Atrato; and six years later, with the plans and results of all these surveys before it, a commission composed of General Humphreys [illegible] U. S. Army; Carlile Patterson, Superintendent U. S. Coast Survey; and Rear Admiral Daniel Ammen, Chief of Bureau of Navigation U. S. Navy; gave its verdict in favor of the Nicaragua route.

The International Canal Congress at Paris, in 1879, had such convincing information placed before it that it was forced, in spite of its prejudices, to admit that, in the advantages it offered for the construction of a lock canal, the Nicaragua route was superior to any other across the American isthmus.

In 187[illegible], and again in 1880, Civil Engineer A. G. Menocal, U. S. N., the chief engineer of previous governmental surveys, resurveyed and revised portions of the route, and in 1885 the same engineer, assisted by myself, surveyed an entirely new line on the Caribbean side, from Greytown to the San Juan river, near the mouth of the San Carlos.

On the eastern side of Nicaragua, all these surveys (except the last), were confined almost entirely to the San Juan river, and its immediate banks; and the country on either side beyond these

narrow limits was, up to 1885, almost entirely unknown. Between Lake Nicaragua and the Pacific, however, every pass from the Bay of Salinas to the Gulf of Fonseca had been examined.

In 1885 the party of which I was a member pushed a nearly direct line across the country from a point on the San Juan, about three miles below the mouth of the Rio San Carlos, to Greytown, a distance of thirty-one miles by our line, as compared with fifty-six miles by the river and forty-two miles by the former proposed canal route.

In December, 1887, I was sent in charge of a final surveying expedition, consisting of some forty engineers and assistants and one hundred and fifty laborers, to resurvey and stake out the route of the canal preparatory to the work of construction.

The information and personal experience gained on previous surveys rendered it possible, without loss of time, to locate the various sections of the expedition in the most advantageous manner and push the work with the greatest speed consistent with accuracy.

The location lines of the previous surveys were taken as a preliminary line and carefully remeasured and re-leveled. Preliminary offsets were run, the location made, and staked off upon the ground; offsets run from three hundred to one hundred feet apart, extending beyond the slope limits of the canal; borings made at frequent intervals, and all streams gauged.

The result of this work was a series of detailed charts and profiles, based upon rigidly verified instrumental data, and covering the location line from Greytown to Brito, from which to estimate quantities and cost.

As may be imagined, [illegible] the prosecution of a survey in these regions is an arduous and difficult work, and one demanding special qualifications in the engineer. The days are filled with a succession of surprises, usually disagreeable, and constant alertness [illegible] of the unexpected. [illegible] the traveler, explorer, or engineer [illegible] obstacles to his progress.

[illegible] prominent feature of the [illegible] is found [illegible] in the prevailing growth of giant trees and tangled underbrush so dense that it is impossible for even a strong man, [illegible], to force himself through it without a short, heavy sword or machete, which [illegible]

Under these circumstances the most observant engineer and expert woodsman may pass within a hundred feet of the base of a considerable hill and not have a suspicion of its existence, or he may be entirely unaware of the proximity of a stream until he is on the point of stepping over the edge of its precipitous banks.

The topography of the country has to be laboriously felt out, much as a blind man familiarizes himself with his surroundings. In doing this work the indispensable instrument, without which the transit, the level, and indeed the engineer himself is of no use, is the national weapon of Nicaragua, the *machete*, a short, heavy sword.

As soon as he is able to walk, the son of the Nicaraguan *mozo* or *[illegible]* takes as a plaything a piece of iron hoop or an old knife, and imitates his father with his *machete*. As he gets older a broken or worn-out weapon is given him, and when he is able to handle it, a full size *machete* is entrusted to him and he then considers himself a man. From that day on, waking or sleeping, the Nicaraguan's *machete* is always at his side. With it he cuts his way through the woods; with it he builds his camp and his house; with it he kills his game and fish; with it, at a pinch, he shaves himself, or extracts the thorns from his feet; with it he fights his enemies, and with it, when he dies, his comrades dig his grave.

When in the field the chief of a party, equipped with a pocket compass and aneroid barometer, is always skirmishing ahead of the line with a *machetero*, or axeman, to cut a path for him. A [illegible], however, speedily dispenses with the *machetero* and slashes a way for himself much more rapidly.

As soon as he decides which way the line is to go the engineer calls to the *macheteros* and the two best ones immediately begin cutting toward the sound of his voice. They must make a narrow path to him, drive a stake where he was standing, and then turn back toward the other *macheteros*, who have been following them, cutting a wider path and clearing away all trees, vines and branches, so that the transit man can see the flag at the stake. Then as soon as the leading *macheteros* reach him the chief starts off again, and by the time the main body of axemen have reached his former position the lead *macheteros* are cutting toward the sound of his voice in a new position.

As soon as the line is cleared the transit man takes his sight and moves ahead to the stake, the chainmen follow and drive

[illegible] may be cut through it as through a hedge [illegible] and a path has to be worked through it while the sun beats down with fierce intensity, the end of [illegible] becomes almost too hot to touch.

But worse than anything thus far encountered are the *Silico* or [illegible] palm swamps. Some of these in the larger valleys and near the coast are miles in extent.

Overgrown with low, thick *Silico* palms, these swamps are in the wet season absolutely impassable except for monkeys and alligators, and even at the end of the dry season [illegible] with aching heart and weary feet [illegible] every portion of his anatomy [illegible] with the utmost difficulty that he finds a practicable place for [illegible], generally stepping on little [illegible] formed by the trunks of the clusters of palms, [illegible] from point to point [illegible] the [illegible].

[illegible] from high trees [illegible] are by no means easy in a country so [illegible] with its secrets as this, nor are the results reliable without a great expenditure of time, labor, and patience.

On level, undulating and moderately broken ground, the tops of the trees, though they may be one hundred and fifty feet from the ground, are level as the top of a hedge. Even an isolated [illegible] of rounded slope presents hardly better facilities, the trees at the base and on the sides, in their effort to reach the sunlight, grow taller than those on the summit, and there is no one tree that [illegible] all the others.

If, however, an isolated hill of several hundred feet in height be found, its steep sides culminating in a sharp peak, one day's work by three or four good axmen, in cutting neighboring trees, will prepare the way for a study of the general relief and topography of the adjacent country. If after these preliminaries have been completed the engineer imagines that he has only to climb the tree and sketch what he sees, to obtain reliable knowledge of the country, he is doomed to certain surprises in the future. If he makes the ascent during the middle of the day, he will, after he has cooled off and rested from his exhausting efforts, see spread out before him a shimmering landscape in which the uniform green carpet [illegible] rated

al outlines except the more prominent irregularities of the terrane, and I have blended different tints in broad ratios, one of which may be several miles beyond the other, into one of which only the sky profile is evident. Naturally under these conditions estimates of distance may be wide of the truth.

There are two ways of extracting [illegible] information from these tree top reconnaissances. If it be in the rainy season the observer must be prepared to make a day of it, and when he ascends the tree in the morning he takes with him a long light line with which to pull up his coffee and [illegible].

Then aided by the successive showers which sweep across the landscape, leaving fragments of mists in the ravines, and hung by grey screens between two distant ranges and mountains, large regions [illegible] detailed sketch may gradually be made. The time of passage of a [illegible] from one peak to another, or to the coast, may also be [illegible] as a by no means to be deep and clock upon as [illegible].

If it be the dry season, the observer may take his choice between remaining on his perch in the tree from before sunrise to after sunset, or making two ascents, one early in the morning and the other late in the afternoon. In this case the [illegible] morning clouds of mornings, and the gradually settling mists at sunset, together with the coloured lights and shadows at sunrise and sunset, bring out very clearly the [illegible] overlapping of distant ranges, and the course of the larger streams.

This kind of work should be designed to anyone, and besides the arduous labor involved in climbing the large trees, there are other serious annoyances connected with it. The climber is almost certain to disturb some venomous insect which revenges itself by a savage sting which has to be endured [illegible] bothersome also, on some days, are mosquitoes, which, [illegible] by the efforts, may make a place where with severe [illegible] layer, then, though there may not be a mosquito [illegible] base of the tree, the top will be infested with a myriad of minute black flies, which crawl inside and [illegible], and with extreme [illegible] irritation. On the other hand the explorer may [illegible] the pleasant task be partially lifted with the perfume of some [illegible] plant orchid on a neighboring branch, and there is a keener enjoyment in watching the showers as they rush across the green carpet, and in listening to the roar with which the big drops beat upon the tree tops.

The special phase of field work which fell to my personal lot was entirely reconnaissance, consisting of canoe examinations of all streams in the vicinity of the line of the canal, to determine their sources, character of valley and approximate watersheds; of rapid prismatic compass and aneroid trails, to connect [illegible] stream, or valley head with another, or furnish a basis for a general sketch plan of a valley; and of studies of the larger features of the terrane from climbed tree tops.

The last has been already described; as to the second the experience was very similar to that of the parties in running lines. On these occasions three or at most four hardy *huleros* (rubber hunters), composed the party, two carrying the blankets, mosquito bars and provisions for several days, and one or two cutting the lightest possible practicable trail, and marking prominent trees.

In a day's march of from five to eight miles, and this was the utmost that even such a light, active and experienced party could [illegible] day, every possible and some almost impossible kind of traveling was encountered, and thoroughly exhausted men crept into their bars every night.

The canoe reconnaissances were more agreeable, though some most unpleasant as well as most enjoyable memories are connected [illegible].

The innumerable large fallen trees which obstruct the streams and over or through which the canoe must be hauled bodily, the almost inevitable capsizing of the canoe, the mud [illegible] banks on either side and the frequent necessity of lying all night in a bed of mud into which the droves of wild pigs which haunt these valleys have trampled the clayey soil, are among the disagreeable incidents.

From the [illegible] end of [illegible] character of these streams is very different, and between 1884 and [illegible] I have followed them far up into the narrow gorges, the beauty of which is as fresh in my memory as if I had seen them [illegible] yesterday.

The crew of the canoe on these reconnaissances usually consisted of three or four men, and when the canoe had been pushed as far up stream as it was possible for it to go, two of the men were left with it, while the third and I, slinging the blankets, bars and a little coffee, sugar, and [illegible] upon our backs, pushed on [illegible] time. Wading through the shallow water in the bed of the stream, taking bearings and estimating distances, while my *hulero*

followed, ever alert to strike some drowsy beauty of a fish in the clear waters, the source of the stream was generally reached in a day, and never did we make preparations to sleep on some bed of clean, yellow sand washed down by the stream in flood times, but what I had a pavo or turkey hanging from my belt, and my *batero* several fine fish.

Much has been written about the climate of Nicaragua and its effect upon the inhabitants of more northerly countries when exposed to it.

It would seem that the experience of the numerous expeditions sent out by the United States, and the reports of the surgeons attached to those expeditions would have long since settled the matter. To those who cannot understand how there can be such a difference in the climate between two countries so slightly removed as Panama and Nicaragua, and the former possessing a notoriously deadly climate, the experience of the recent surveying expedition must be conclusive.

Only five members of that expedition had ever been in tropical countries before, and [illegible] were yo[illegible] manual labor, nor slept on the ground at night in their lives. Arriving at Greytown during the rainy season, the first work that they encountered was the transporting of their supplies and camp equipage to the sites of the various camps. This had to be done by means of canoes along streams obstructed with logs and fallen trees. Some parties were a week in reaching their destination, wading and swimming by day, cutting and pushing their canoes along, and at night lying down on the ground to sleep.

One party worked for six months in the swamps and lagoons region directly back of Greytown, and several other parties worked for an equal length of time in the equally disagreeable swamps of the valley of the San Francisco. Several of these officers are down there yet, as fresh as ever. In making tours of inspection of the different sections I have repeatedly, for several days and nights at a session, spent the days travelling in the woods through swamps and rain, and the nights sleeping as best I could, curled up under a blanket in a small canoe, while my men paddled from one camp to the next.

In spite of all this exposure that they were forced to undergo on the expedition but there was not a single case of serious illness, and the officers who have returned up to this time, were in better health and weight than when they went away.

Of course the men had the best of food that money could obtain and previous experience suggest, and the chiefs of all parties were required to strictly enforce certain sanitary regulations in regard to coffee in the morning, a thorough wash and dose of spirits on returning from work, and mosquito bars and dry sleeping suits at night; yet the climate must be held principally responsible for a sanitary record which I believe could not be ex[illegible] temperate zone city, with the same number of men, doing the same arduous work under conditions of equal exposure.

The forests everywhere abound in game, and every party which had a man in its personnel a good rifle shot was sure of a constant supply of wild pigs, turkeys, quam and grouse, varied by an occasional deer, all welcomed in the ordinary way [illegible] and surveying [illegible] monkeys, iguanas and macaws.

Parties in the lower valleys of the various streams had no trouble in adding two or three varieties of very toothsome fish to their bill of fare, though these fish were rarely caught with the hook, but usually shot, or lanced by an alert native, as they passed up the shallows. These parties also obtained occasionally a *danta* (tapir) or a manatee.

On the river it was possible to obtain a fine string of fish with hook and line, then there was the huge tarpon to be had for the spearing, and fish pots sunk in suitable places were sure to [illegible] a mess of fresh water lobsters. Turtles were also [illegible]

The forms of life are even more numerous in the vegetable than in the animal kingdom. The effect of these wonderful forests [illegible], and though many writers have essayed a description, I have yet to see one that could be adequate to the subject [illegible]. Only a [illegible] forest consisting of giant bodies of the forest, large mahogany, [illegible] cedar, cottonwood and palm [illegible] trees, [illegible] rising one hundred and fifty or two hundred feet [illegible] the [illegible]

[illegible] of these great trunks reaching up a hundred feet or more [illegible]

[illegible] Some trees straight and smooth, and [illegible]

[illegible] feet [illegible] rubber [illegible]

But whatever the form of the tree trunks may be, the shallow soil upon the hills and the marshy soil in the lowlands, has taught them that there is greater safety and stability in a broad foundation than in a deeply penetrating one, and so almost without exception the tree roots spread out widely, on, or near, the surface. Beneath the protecting shelter of these patriarchs, as completely protected from scorching sun and rushing wind as if in a conservatory, grow innumerable varieties of palms, young trees destined some day to be giants themselves, and others which never attain a great size. Still lower down, luxuriate smaller palms, tree ferns, and dense underbrush, and countless vines. These latter, however, are by no means confined to the underbrush; many of them climb to the very tops of the tallest trees, cling about their trunks and bind them to other trees and to the ground with the toughest of ropes. With one or two exceptions these vines are an unmitigated nuisance. To them more than to anything else is due the impenetrableness of the tropical thicket. Of all sizes and as tough as hempen ropes, they creep along the ground, catching the traveler's feet in a mesh from which release is possible only by cutting. They hold the underbrush together in a tough, elastic mat, which catches and holds on to every projection about the clothes, jerking the cover from one's head, and wrenching the rifle from the hand, or, hanging in tangled loops from the trees, catch one about the neck, or constantly drag one's hat from the head. The one exception noted above is the *bejuco de agua* or water vine. This vine, which looks like an old worn manila rope, is to be found hanging from or twined about almost every large tree upon elevated ground, and to the hot and thirsty explorer it furnishes a most deliciously cool and clear draught.

Seizing the vine in the left hand, a stroke of the *machete* severs it a foot or two below the hand, and another quick stroke severs it again above the hand; immediately a stream of clear, tasteless water issues from the lower end and may be caught in a cup or allowed to flow directly into the mouth. A three foot length of two inches in diameter will furnish at least a pint of water. The order of cutting mentioned above must invariably be adhered to, otherwise, if the upper cut be made first, the thirsty traveler will find he has in his hand only a piece of dry cork-like rope.

It is practically impossible to judge of the age of the huge trees in these forests. Mighty with inherent strength, stayed to the

around and to their fellows of the numerous vines, sheltered and protected also by their fellows from the shock of storms, their huge trunks have little to do except support the direct weight of the tops, and they rarely fall onto, they have resisted the last stages of decay. Then some day too much moisture, or a hurricane, or two of water dropped from some furious tropical shower, or the vibration from a hurrying troop of monkeys, or the spring of a leaper, is too much for one of the great branches heavy with the mass of leaves and parasites, and it gives way, breaking the vines on every direction and splintering a huge scar from bole to outermost trunk. When the soft parts thus broken at the wound weight of the remaining branches on one side, the weakened trunk sways for a moment then bows to its fall. The vines snap their trunk with the reckless strength, and the old giant plunging heavily as his fall are dragging with him everything to his ruin, crashes to the earth with a noise which gives a crash of terror for miles and leaves the image there of the quivering forest like the report of a heavy cannon. A patch of fine sky overhead and a pile of impenetrable debris below, mark for years the grave of the old tree.

As regards the insect and reptile pests of the country, I have been very experience that both the numbers and species of the former have been greatly exaggerated. Mosquitoes, flies of various sizes, wasps and stinging ants exist, and few that is the places in large numbers; yet to a person who has any of the woodsman's craft of taking care of oneself, and who does not abnormally sensitive to insect poisons, these pests are terrible and not alarming nuisances. At the hour of encamp on sand bar the mosquito, we had no insignificant flies to torment, and even after sunset they were not especially numerous. At another camp by a few miles away there were black flies only and no sand flies, at the other hour, when at the camps up in the hills there were neither. It was only at camps in the wet lowlands and near swamps, that they became a almost unbearable annoyance. Even here as true Indians who encamped in camp that suffered most. Men out in the three much were but little annoyed by them, and when on their return to camp they had finished their supper and gotten into their mosquito bars they were out of their reach. As for snakes, the danger from them even to a European, is practically nothing. Not a man of the several hundred that have been engaged in the

[illegible]

There are very few islands in this section of the river, the banks are covered with huge rocks and with a few small trees and bushes. From Fort Reid to the mouth of the San Juan the river is confined between steep hills and

As a result of the presence of considerable rapids already noted, the physical features of this portion of the river contrast with those of the lower, and entirely different, conditions prevail.

Below the Rio San Juan the river becomes of a character entirely different. Its average width is twelve hundred and fifty feet, its bottom is sandy, there are numerous islands, and the slope of the river is almost uniformly one foot per mile.

The discharge into this section of two large tributaries, the San Carlos and the Sarapiqui, descending from the steep slopes of the Costa Rican and Nicaraguan mountains, causes much greater fluctuations and considerably greater discharges than in the upper river.

While the lower portion of the river and especially the delta present very interesting features, yet the peculiar charm of the river is to be sought for in the upper section, and all the experience gathered from the study of rapid water navigation offers for a thorough knowledge of this portion of the river. The portion of the river with the lake and the narrow estuary between it and the mouth of the San Juan would form a natural harbor for the construction of a canal, the importance of which it would be difficult to overestimate.

About three miles below the mouth of the San Carlos, the Castillo Viejo, or San Juan del Norte, is reached. This stream, about a hundred feet wide and from eight to ten feet deep, is the last of the rapids encountered in the course of the San Juan. It can scarcely be said to have a valley, but rather a wide bed of a rugged nature extending for several miles northerly and northwesterly up into the eastern flank of the cordillera. Every variety of granite rock, from a fine-grained quartz to the coarse, green-black hypersthene, may be picked up in the bed of this stream. Agates also are quite abundant, and occasional masses of jasper. Particularly frequent outcrops of rock in situ occur, in proximity to which localities with a diameter varying

Twelve miles below the mouth of the San Francisco enters the San Juan. This stream, with its several tributaries, drains a large swampy valley sprinkled with irregular hummocks and low,

[illegible] San Juan [illegible], and its stream [illegible], and then a rocky bed, it finally disappears in steep ravines filled with huge bowlders. The main San Francisco comes from the northwest, but a large tributary has its source to the eastward in a range of hills which separates the San Francisco basin from the immediate Caribbean water-shed. This range, unlike the ones already noted, is at heart an uninterrupted mass of homogeneous hypersthene andesite, and with one exception nothing but fragments of trap or trap *in situ*, is to be found in any of the streams descending from either its western or eastern slopes. The one exception is the Cañita Maria, a tributary of the San Francisco, entering it but little more than a mile from the San Juan. In the bed of this stream were abundant specimens of agates, jasper, and petrified woods of several varieties in a wonderfully good state of preservation.

This range of hills ends at the Tamborcito bend of the San Juan, four miles below the mouth of the San Francisco, and is the [illegible] interest. Between it and the coast there are, however, mountain masses of equal or greater elevation, notably "El Irigante" and the Solentiname, the former some fifteen hundred feet high, but these are simply isolated mountain ganglia, their ramifications radiating spurs speedily giving way to swamps or river valleys.

The streams that flow down the eastern slope of the Sierra Iliare, from their sources to the lowlands, of almost idyllic beauty. Beginning as noisy little brooks tumbling over black rocks in a [illegible] every now and then as sheets of white spray over worn ledges forming here and there deep green pools, and then after they have [illegible] reaches over sandy beds of bright yellow gravel. The water of these streams is clear and sparkling as that of an Alpine stream and apparently almost as cool. The insect pests of the tropics are unknown in the elevated portions of their valleys, and I have slept [illegible] without [illegible] the [illegible] "snakes," tumbling through the trees above me, brought the murmur of the Caribbean surf miles away, to mingle with that of the stream.

The soil of this range consists, to a depth of ten to forty feet, of clay of various grades and colors, red prevailing. In the valleys this clay is almost invariably of a very dense consistency, and deep, dark red in color.

From the foothills of the range to the coast, as a low level stretch of country, a dozen miles wide, interspersed with lagoons and swamps. Near the bluffs, where the elevation of the ground will average about fifteen feet above sea level, the soil is composed almost entirely of the before mentioned red clay, which occasionally assumes the form of hummocks. Within a short distance, as one goes toward the coast this strata of clay gradually disappears under a layer of sand, which is in turn covered by a vegetable mould, to a depth of a few feet. From this point to the sea the average elevation is barely five feet above the sea level, and the sand and mould above mentioned are the only materials met. A short distance from the ocean the vegetable earth-covering disappears and only the sand is left, extending out to an unknown depth and reaching out into the sea.

West of Lake Narmona, from the Rio Lagunas to Brito, as we leave the lake shore, the ground rises almost imperceptibly to the "Divide" among cleared and gently undulating hills. Then [illegible] the [illegible] gorge of the Barranca de [illegible] Arroyo, a few [illegible] into the upper end of the Rio Grande and [illegible].

To the right the Tres Marias stretches to the southward, and all around high and wooded hills encircle the valley except directly in front where a narrow gateway to the coast hills opens to the Pacific. In the bottom of this valley are a few farms and through it wander devious roads. Beyond the narrow gateway in the hills, less than three miles of level swampy plateau reach to the surf of the Pacific.

The views from the hills which flank the gateway of the Rio Grande, at La Boca, are wonderfully attractive. I well remember one camp on the hillside, from which in one direction the eye takes in the fertile valley of the Tres and Rio Grande, backed by the mining hills of the "Divide" and over them the symmetrical peak of Orizaba, its base washed by the waves of this great lake. In the other direction the Pacific lies apparently but a stone's throw beyond, the noise of [illegible] at times very [illegible].

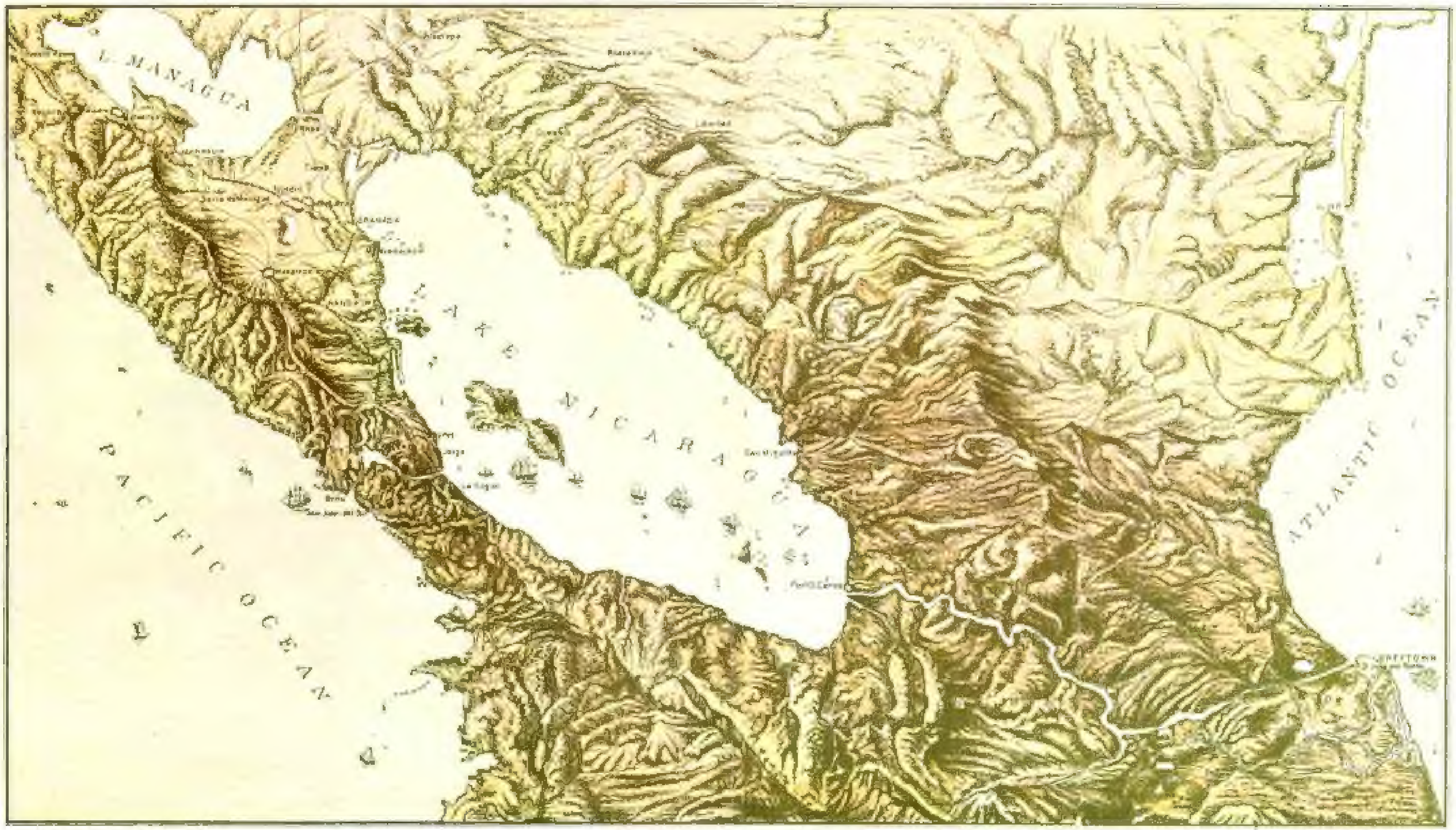
[illegible] expresses himself something as follows:

"What if, in the camp, we should, like Rip Van Winkle, sleep for ten years, and then awakening look about us? We are still at Home, but instead of being in the wilderness, we look down upon a thriving city. In the harbor are ships from all ports of the world. Ships from San Francisco, bound for New York, shun to pass through the canal and shorten their journey by [illegible] miles. Ships from Valparaiso, headed for New York, which will take the short cut and save many miles and the dread storms of Cape Horn. As many a merchant flies the British flag, and vessels from Liverpool, with their bows turned towards San Francisco, have shortened their journey by 7000 miles."

"We go aboard one of the many steamers flying the "stars and stripes" and start eastward. All along the route the face of the country has changed, the fertile shores of the Chagres are occupied by cocoa plantations, fields have replaced forests, villages have grown to towns, and factories driven by the exhaustless water power furnished by the canal have sprung up on every available site."

"Along the shore of the lake are immense dry docks, and vessels are coming in this huge fresh water harbor before setting out again on the long voyages. The broad bosom of the noble San Juan is quivering with the strokes of oarsmen propelling us. The roar of the great dam at Gatun is heard for a moment and then the eastern section of the canal is entered. Here the country is scarcely recognizable as greatly has it changed. Wilderness and marsh have disappeared, and only great fields of plantains and bananas and dark green orange groves are to be seen. A day from Bas to and the steamer's bow is rising to the long low swell of the Caribbean at Greytown."

Well may this picture raise and breathe enthusiasm, for it means the dream of centuries realized, the cry of commerce answered, and our imperial Ocean and Ocean-fleeting Republic resting content with coasts united from Eastport to the Strait of Fuca.



THE NICARAGUA CANAL